Research Article

Examination of the Estimation Skills of 6th Grade Students and the Process of Comparison of their Estimations with Real Measurement Values[*]

İmren AYDOĞDU [1] (iD)   **Emre EV ÇİMEN** [2] (iD)

Abstract

The aim of this research was to examine the measurement-based estimation skill levels of middle school 6th grade students and the processes of comparing their estimations with measurements. In this research, the case study design, one of the qualitative research methods, was used. Six students one female and one male student, at low, medium and high mathematics achievement levels from a public middle school in the central districts of Ankara formed the study group. Activities were prepared, which included questions in different categories, both for estimating the length, area and liquid volume of the measurement, and for the proximity of objects to the student. In order to determine the study group, activities were applied to 35 students, and their measurement-based estimation skill levels were examined. While determining the levels, a method called "Evaluation of estimates by percentage of measurements" was used. Before conducting clinical interviews with the study group, the activities were applied to the students, the students were first allowed to make predictions, they were expected to compare their estimations with the possible real measurement without measuring, and then, in some questions, the students were asked to make measurements using tools and compare their estimations with the measurements. As a result, it was observed that the students' estimation skills based on measurement were at a low level. When they were asked to evaluate their estimations without measuring, it was concluded that the students were not successful and they had problems both in the use of measurement tools and in the measurement process while measuring.

Keywords: Mathematics education, estimation, operation-based (operational) estimation, measurement-based estimation

1. INTRODUCTION

As a result of developing technology and information production, there is a change in many areas and education is among the areas affected by this change. Today, the changes in general education and teaching approaches, ways and methods have also shown their effect in mathematics education. Instead of teaching activities focused on operation skills in traditional paper-pencil applications, a new system in which the aim is to learn by doing and living, many new tools, equipment and technologies are used, and activities that develop high-level thinking skills are implemented. Developing high-level thinking skills, such as associating mathematics with daily life and other disciplines, problem solving, reasoning, estimation, both in real life and in mathematics teaching has gained importance and priority. One of these skills, estimation is also an indicator of the reasoning process and is an important skill that demonstrates mathematics can be taught without depending on traditional paper-pencil applications (Ministry of National Education [MoNE], 2009, p. 7; 2013).

Estimation, which is an important skill that we often use in meeting our daily needs, can be defined as making estimations about the consequences of an event or situation that did not happen without doing any work. In mathematics, estimation is nothing more than counting or measuring for the amount or size of something, and developing an idea quickly and appropriately (Micklo, 1999).

While there are different expressions when defining estimation in mathematics, there are also differences in the literature on estimation diversification. As there are studies stating that there are three types of estimation: operational, measurement-based and batch estimation (Berry, 1998; Heinrich, 1998; Dowker, 1992; Cited by Pilten & Yener, 2009, p. 65), there are also studies stating that there are two types of estimation: operational and measurement-based estimations (Segovia & Castro, 2009; MoNE, 2009, p. 17). In the MoNE Mathematics Curriculum, the strategy used when estimating the multiplicities is the same as the reference selection strategy used in the measurement-based estimation, and the heap estimation is considered in the estimation based on measurement. In this research, estimation is handled in two ways as operation-based (operational) estimation and measurement-based estimation.

Operational estimation is based on estimating the outcome without taking any action. On the other hand, measurement based estimation is to estimate the measurement result without doing any measurement work. The measurement to be estimated here can be one of the sub-dimensions of measurement such as length, area, volume, or it can be the number of any object. As seen here, measurement, which consists of many dimensions, is one of the most important concepts of daily life applications of mathematics. In the most general sense, measurement is to compare a feature of an object or situation with a quantity accepted as a unit of the same feature (Baykul, 2009). It is more possible to make the measurement work correctly by directing the children correctly at a young age. There are studies indicating that young children's understanding of measurement improves significantly with estimation exercises (Haylock & Cockburn, 2014). This proves the strength of the link between measurement and estimation.

Some of the benefits of estimation in measurement and the reasons for using it in curricula are as follows (Baykul, 2009; Hildreth, 1983; Walle, 2004):

• Students are more likely to draw their attention to the measured feature, the logic of the process and concepts.

• Estimation forms the general framework of measurement units in the mind of the student.

• Estimation is a fun, experiential, practical skill.

• Estimation contributes to the development of unit and size concepts in students.

While talking about the benefit of estimation in measurement, according to the TIMSS (Trends in International Mathematics and Science Study) - 1999 Report, when the subject distribution of the questions in the exam is examined, it is seen that only the estimation skill is lacking which is aimed to be taught in Turkey (Türnüklü, et al., 2005). In the Mathematics Curriculum (p. 20) of the Ministry of National Education in 2009, it was stated that the estimation strategies of the students would not develop spontaneously, and that both the estimations and the strategies of the students would develop with the triple process of estimate-measure-check. This shows the benefit of controlling the estimations.

When the literature is examined, it is seen that the studies related to measurement-based estimation abroad (Gooya, Khosroshahi, & Teppo, 2011; Hildreth, 1983; Forrester & Shir, 1994; Pizarro, Gorgorio, & Albarracin, 2015; Melinski, 2014; Segovia & Castro, 2009; Siegel, Goldmith & Madson, 1982; Taylor, Simms, Kim & Reys, 2001) are considerably less than the number of studies on operational estimation. Studies on measurement-based estimation (Boyraz, 2017; Bozkurt & Yavaşca, 2021; Kumandaş & Gündüz, 2014; Kılıç & Olkun, 2013) are seen in Turkey. Other studies on estimation in Turkey (Aslan, 2011; Aydoğdu & Ev-Çimen, 2019; Ayvali, 2013; Aytekin, 2012; Boz, 2004, 2009; Boz & Bulut 2002; Ayyıldız, 2014; Bulut, Yavuz & Boz Yaman, 2017; Boyraz & Aygün, 2017; Boz-Yaman & Bulut, 2017; Çakır, 2019; Çilingir, 2018; Er, 2014; Köse, 2013; Pilten & Yener, 2009; Seferoğlu, 2015; Özcan, 2015) are also seen to be insufficient.

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When the studies are examined, the scarcity of studies on measurement-based estimation, the lack of control of estimations in the studies and the fact that students were not made to measure after estimating shows the need for this research.

The aim of this research is to examine the measurement-based estimation skills of middle school students and the processes of comparing their estimations with measurements. Here, students were asked to compare their estimations with estimations both before and after measurement. The process of having students take measurements after their estimates and comparing their estimates with their measurements shows the most different aspect of this research from other studies.

The research questions for this purpose are as follows:
• What is the level of students' estimation skills based on measurement?
• What are the students' views when asked to compare their estimates with possible real values without measuring?
• What do the students experience when they are asked to make measurements and compare their estimations with the measurements?

2. METHOD

Qualitative research is a method that can see the researched subject from the perspective of individuals and reveal the social structure and process in the perspective (Yıldırım & Şimşek, 2008). Due to the fact that it is more suitable for the purpose of the research, the case study design, which is one of the qualitative research methods, was used. The non-generalization feature of the case study strips this design from quantitative research designs and allows it to be included among the designs of qualitative research methods (Karasar, 2009). Since there is no generalization in qualitative research, purposive sampling is used in which cases with rich information suitable for the purpose of the research are examined in depth (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz, & Demirel, 2017).

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Sixth grade students studying in one of the state middle schools located in one of the central districts of Ankara province in the 2018-2019 academic year participated in the research. In order to determine the study group, a general application was made to 35 students from two branches at the sixth grade level. In general practice, activities to determine students' measurement-based estimation skills were applied. The implemented activities consisted of 12 questions and each question was evaluated over 1 point. The highest score to be obtained from this application was 12, and the highest score in this research was 7 points. The student with the highest score (7 points) from male students and the student with the highest score (5 points) from female students were directly included in the study group. There was more than one student who got 4 points from male students and 3 points from female students, and zero points in both genders. Considering the explanations and some personal characteristics of these students in practice, one student from each of these students was included in the study group as middle and low level. As a result of the general practice, a total of six students, one male and one female from low, medium and high levels, formed the study group of the research. The reasons for including the participant students can be explained as follows by their code names:

• *Asya:* She is one of the female students with the lowest score in practice. Although her estimations in practice were not within the range of values she could score, the detailed explanations she made to the questions and the fact that she was a student who could ask questions without hesitation in the parts she did not understand in mathematics lessons.

• *Barış:* He is one of the male students who got the lowest score in the application. Although his estimations in the application were not within the range of values he could score, the unrounded results in his answers attracted attention.

• *Eda:* She is one of the female students who got an intermediate score in practice. The fact that she had different approaches to the questions during the application compared to her friends, her detailed explanations and her non-shy nature.

• *Tuna:* He is one of the male students with an intermediate level after the application. The differences from others in his explanations in the application and his frank personality.

• *Helin:* Being the student with the highest score in practice among female students. In addition, her natural structure, sociable and frank attitude drawed attention in the application.

• *İrfan:* He got the highest score among all students in practice. Although he is not a very talkative person, he is an academically active student.

In order to remind these students about the levels in practice, a "*" was placed next to their names, as 1 (*) at low level, 2 (**) at medium level, and 3 (***) at high level.

2.1. Data Collection Instruments and the Procedure

The activity used in general practice to determine the study group consists of three categories. The first category consists of estimation questions about the length, area and volume of the objects they can see during the application. The second category includes questions about estimating the sizes of objects that students have encountered before. The third category consisted of questions that were expected to estimate the length, area or volume of the objects through the photograph. While preparing the activity questions, a pilot application was carried out after taking expert opinions. After the pilot implementation, expert opinion was taken again for the arrangements made in the activities and the activities were finalized. One of the questions in these activities is given in Figure 1, Figure 2 and Figure 3.

Question 1- You want to decorate the classroom board with a ribbon for a birthday. Estimate how long ribbon is needed.
- ➢ Your estimation: …………………………………………………………………………….
- ➢ Explain how you estimated.
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Figure 1. An example of a question from the activity in the first category

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Question 3- Pancakes will be sold at the bazaar. A tablespoon of oil will be used to cook one pancake. If it is anticipated that 50 pancakes will be sold, estimate the volume of oil needed.
- ➢ Your estimation: …………………………………………………………………………….
- ➢ Explain how you estimated.
………………………………………………………………………………………………………
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Figure 2. An example of a question from the activity in the second category
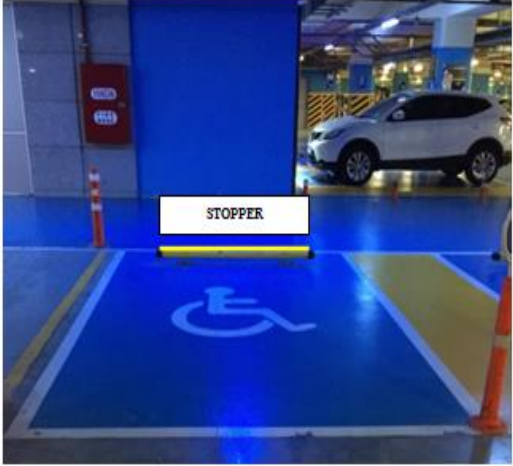
Question 5- The borders of the disabled parking lot given in the adjacent photo are indicated with a white line. If the length of the yellow stopper is 2 meters, estimate how many square meters the area of the disabled parking lot is.

➢ Your estimation:

……………………………….

➢ Explain how you estimated.

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Figure 3. An example of a question from the activity in the third category

After the study group was determined, permission was obtained from these students and their parents for their participation in the study and video recording. One session of clinical interview was conducted with these six students. These interviews were recorded with video and the movements of the students in the estimation process were also examined by the observation technique.

In the clinical interview, some of the questions asked to the students in the general practice were asked directly with the same content but with their expressions removed from the activity. The question in the general practice in Figure 1, asked in the clinical interview, is "Can you estimate the perimeter of the classroom board?" There was enough time between the general practice and the clinical interview that the students did not remember the questions.

In addition, in the clinical interview, they were asked to estimate the object, whose image was given in a different format than the general practice, by first looking at the photograph, and then they were expected to estimate by being next to the object. In this format, an example of which is given in Figure 4, the image in option "a" was given to the student first, and the student was expected to make a an estimate, then go down to the garden where the bust is located and estimate next to the bust. Clinical interviews lasted an average of one hour each. During this period, the students first made an estimate for each question, and then they were expected to measure after estimating in some predetermined questions that could be measured. Necessary tools were given to the students for measurement.

Question 8-

  a) If the bust of Atatürk at your school is 140 cm above the ground (indicated by the blue line), can you guess the area of the floor (indicated by the red line) on which the bust is located?

  b) Can you guess the area of the floor of the Atatürk bust by looking at it?

Figure 4. Example of a question from the clinical interview

Data diversity was used for the reliability of the research. In addition, a pilot application was made for the data collection tools and the opinions of the experts were taken. The data were analyzed in two ways, namely the analysis of student estimates and the analysis of qualitative data.

There are differences in the literature in the evaluation of estimates. In the estimations, lower and upper limits are determined according to a certain percentage of the real measurement, and estimations falling between these limits are accepted. Siegel, Goldsmith and Madson (1982, p. 217) took the interval as 50%, while Baroody and Gatzke (1991, p. 63) took this interval as 25%. Van de Walle et al. (2014) stated that 10% range for length and 30% range for weight and volume may be appropriate (Cited by Boyraz, 2017, p. 65). In this study, among the estimates obtained from the general practice, those between the 25% lower and upper limits of the real measurement were evaluated to receive "one" score, and those outside the limits were given "zero" score. A different evaluation method from the literature was used to evaluate the estimates obtained from clinical interviews. The evaluation approach used in the research is given in Table 1 below.

Table 1. Evaluation of estimation by the percentage of measurements

Operation	Evaluation
$\left(\dfrac{Estimation}{Measurement}\right) \cdot 100$	If the result is 0 then zero score is given. If the result is between 0 and 100 then the result is given directly as score. If the result is 100 then hundred score is given. If the result is between 100 and 200 then the its difference from 200 is given as score. If the result is 200 or greater then 200 then zero score is given.

For example, according to Table 1, a student who estimates 120 cm for an object with a measurement result of 150 cm, gets 80 points because $(120/150) \cdot 100 = 80$, while a student with an estimation of 330 cm $(330/150) \cdot 100 = 220$ and since $220>200$, gets zero score.

In addition, coding was used in the analysis of the data obtained from the video recordings of the clinical interviews, which Miles, Huberman and Saldana (2014, p. 72) believe is a deep reflection in the in-depth analysis and interpretation of the meanings of the data. Miles and Huberman (1994) emphasize the importance of coding for qualitative research and analyze the stages of organizing the data with coding and notes, presenting the data, formatting the results.

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3. FINDINGS

According to the research questions, the findings were discussed under three separate titles. In the first title, findings related to the evaluation of students' estimates are given. In the second title, there are findings related to the comparison of the students' estimates with the measurements that can be made without any measurement, while the third title includes the findings related to the processes of making measurements and comparing their estimates with measurement.

3.1. Findings from Clinical Interviews

Student estimates as a result of clinical interviews with students were evaluated according to Table 1 and their scores are given in Table 2.

Table 2. Scores obtained by students in clinical interviews

Sub-Dimensions	Questions	Asya*	Barış*	Eda**	Tuna**	Helin***	İrfan***	Average Score
Length	Classroom board	65	20	90	68	61	90	65.66
	Court height	0	0	11	65	95	79	41.66
	Turkish Flag image	96	20	100	50	54	93	68.83
	Turkish Flag	65	70	100	97	43	85	76.66
Area	Teacher table	0	0	32	0	63	56	25.16
	Court floor	51	2	7	3	6	12	13.50
	Ataturk Bust image	30	1	0	5	29	90	25.83
	Ataturk Bust	31	1	38	46	51	70	39.50
Volume	Fruit juice	1	55	0	55	0	70	30.16
	Olive oil	0	85	0	60	0	67	35.33
	Syrup bottle image	27	42	44	67	0	84	44.00
	Syrup bottle	40	1	44	80	0	74	39.83

When the scores of the students in each question are examined, it is seen that the lowest score is zero and the highest score is 100. Eda** was the only student to score a hundred points. Eda** made an estimate equal to the length that should be in the Turkish Flag question. All the estimations of İrfan***, who never got a zero score, were within the acceptable range. Asya* 3, Barış* 2, Eda** 3, Helin*** 4 and Tuna** in 1 question got zero points. No student scored zero in five of the twelve questions (Classroom board, Court floor, Ataturk Bust, Turkish Flag and Turkish Flag image).

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When the average score of the questions is examined, it is seen that the most successful estimations were made in the Turkish Flag question (76.66), and the lowest average was in the court floor area question (13.50).

When the results of the students were evaluated in general, İrfan*** got the highest score, while Barış* got the lowest score. When evaluated according to length, area and volume estimates, İrfan*** got the highest score in all three categories. While Barış* got the lowest score in length and area estimation, Helin*** could not score in volume estimation. When evaluated according to the type of activity, İrfan*** was the student with the highest score in all three categories. The lowest scores belonged to; Asya* in the first category, Eda** in the second category, and Barış* in the third category.

When the averages of the students' estimates were evaluated according to the sub-dimensions of the measurement, the scores given in Table 3 were obtained.

Table 3. Average scores obtained from students' estimates according to the sub-dimensions of the measurement

Sub-Dimensions	Asya*	Barış*	Eda**	Tuna**	Helin***	İrfan***	Average
Length	56.50	27.50	75.25	70.00	63.25	86.75	63.21
Area	28.00	1.00	19.25	13.50	37.25	57.00	26.00
Volume	17.00	45.75	22.00	65.50	0.00	73.75	37.33
General Average	33.83	24.75	38.83	49.66	33.50	72.50	42.18

When the general average scores of the questions were evaluated, it was found that the average of all students was 42.18. This revealed that the estimation skill was lower than medium level. In terms of the sub-dimensions of measurement, it was seen that the highest average (63.21) was in length estimation. It was also seen that the volume estimation followed the length estimation (37.33), while the lowest average (26.00) belonged to the area estimation.

When the student results according to the activities were evaluated as in Table 4, it was found that the students were the most successful in the third category of activities (49.11).

Table 4. Students' average scores according to activity categories

Categories	Asya*	Barış*	Eda**	Tuna**	Helin***	İrfan***	Average
First category	22.00	25.00	40.67	41.00	41.33	72.00	40.33
Second category	17.00	29.00	6.00	42.66	33.66	52.66	30.16
Third category photo	51.00	21.00	48.00	40.67	27.67	89.00	46.22
Third category object	45.33	24.00	60.66	74.33	31.33	76.33	51.99
Third category	48.17	22.50	54.33	57.50	29.50	82.67	49.11
General Average	33.83	24.75	38.83	49.66	33.50	72.50	42.18

Students who were less successful (46.22) at the photography stage of the third category got higher points (51.99) when they estimated next to the objects. In the first category (40.33), the students made more successful estimations than in the second category (30.16).

When Table 3 and Table 4 are examined, the general average of the estimates for Asya* is 33.83 out of 100. When the results are evaluated on the basis of activity; Asya* had higher success in the third category (48.17) and lowest success in the second category (17.00).In the third category, the average score of the questions in which she used photographs was 51.00; 45.33 in the question she made estimations by looking at the post-photo objects in person. She had higher success in questions with photos. According to the sub-dimensions of the measurement, Asya* had the most success in length estimation (56.50), while she had the lowest success in volume estimation (17.00).

The average score of Barış*'s estimations is 24.75. Although there are no significant differences between his results when evaluated on the basis of activity; Barış* had a higher average in the second (29.00) category. The second category is followed by the first (25.00) and the third (22.50) categories, respectively. In the third category, Barış*, who got a higher score (24.00) when he went near the objects, got a lower (21.00) score when he made an estimation using the photographs. When evaluated according to the sub-dimensions of the measurement; While Barış* showed the highest performance in the volume estimation (45.75), he showed the lowest performance in the court estimation (1.00).

When the results of Eda** are examined, it is seen that the average score is 38.83. When the results are evaluated on the basis of activity; it is seen that Eda** was much more successful in the questions in which she made estimations in the third category (54.33) and in the first category (40.67) than the second category (6.00). In the third category with her highest score; Eda** showed a higher performance in the questions with objects (60.66) than her estimations using the photographs (48.00). When the estimations are examined according to the sub-dimensions of the measurement; Eda**, who showed the highest performance in length estimation (75.25), showed much lower performance in area estimation (19.25) and volume estimation (22.00).

The average of Tuna**'s estimates is 49.66. When evaluated according to activities, Tuna**; performed close to each other in the first category (41.00) and the second category (42.66). The questions in the third category (57.50) performed higher than the other activities. In the third category;

Tuna**, who showed a low success (40.67) when he used photographs, increased his performance (74.33) when he answered the questions next to the objects. When evaluated according to the sub-dimensions of the measurement, the highest performance was shown in the length estimation (70.00), while the performance in the volume estimation followed it. In the area (13.50) estimation, the difference compared to the length and volume estimation (65.50) increased and showed the lowest performance in the area estimation.

The average score of Helin***'s estimates is 33.50. When the results are evaluated on the basis of activity; it is seen that there is not much difference between the efficacy results. While the activity in which Helin*** was most successful was in the first category (41.33), the activity with the lowest score was in the third category (29.50). In the third category, she showed lower performance when using photographs (27.67) and higher performance when estimating by examining the object without using photographs (31.33). According to the sub-dimensions of the measurement, Helin*** was the most successful in length estimation (63.25), while she was less successful in area estimation (37.25) than length estimation. In the estimation of the volume, it was not scored because it could not make estimations within the acceptable range for any question.

The general average score of İrfan***'s estimates is 72.50. İrfan*** was the student with the highest score in the application. When the estimations of İrfan*** are evaluated according to the activities; it was determined that the highest performance was found in the third category (82.67). İrfan*** showed similar performances in other event categories; scored higher in the first category (72.00) than the second category (52.66) with a slight difference of one point. In the third category, İrfan*** showed a higher performance when he used the photographs in the questions (89.00), and his performance decreased slightly when he made estimations next to the objects (76.33). When evaluated according to the sub-dimensions of the measurement, İrfan*** showed the highest performance in the length estimation (86.75), and the lowest performance in the court area estimation (57.00). In the volume estimation (73.75), he performed slightly less than the length estimation.

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In determining the study group, Helin*** got the highest score among the girls, and the girl student got the lowest score in this application. Eda**, who got a medium score in determining the study group, was the female student who got the highest score in this application. Eda** being the student with the highest score among girls in this application; questions and remembering what she did is thought to have an effect. In the evaluation made among men in the determination of the study group, İrfan*** got the highest score and Barış* got the lowest score. In this application, Tuna** received a moderate score. Considering the academic grade averages of male students, the student with the highest average is İrfan***. While Tuna** is a middle-level success student, Barış* is one of the lowest-level students. When the results of the activities in the selection of the study group are evaluated, İrfan*** is the most successful, Tuna** is a moderately successful student, and Barış* is one of the students with the lowest success. This is in line with the results obtained from the clinical interviews. According to the results of clinical interviews, İrfan*** is the student with the highest performance and Barış* is the student with the lowest performance.

In the research, there are conflicting situations as well as agreement between the results. In the evaluation of selection of the study group among female students, Helin*** got the highest score but she could not get the highest score among the girls in the clinical interviews. Even though the scores of two female students in the clinical interview were very close to each other, Helin*** was the female student with the lowest score by a very small margin. When the students' academic levels at school and their estimation skills were compared, some contradictory situations were encountered. Helin***, who is one of the students with the highest academic grade point average, has the lowest estimation skills. Asya* was included in the study because she was one of the students with the lowest score in determining the study group, while her academic GPA was at a medium level. While Helin***, Eda** and Asya* ranked from the most successful to the least successful according to their academic grade

averages, when the estimation skills were evaluated, it was revealed that Eda** had the highest estimation skills and Helin*** had the lowest estimation skills.

There is a concordance between ranking male students according to their academic grade averages and ranking them according to their estimation skills. İrfan*** was the most successful in terms of academic grade point averages, and he was also the most successful male student in terms of estimation skills. However, in general, students' estimation skills are at a lower level than their academic achievements.

3.2. Findings from the Process of Interpreting Estimates Made without Measurement

After the students made an estimation, they compared their estimations with the possible measurement without making any measurements. Here, students were expected to interpret their own estimations.

The comparison of the students' estimations with the measurements is given in Table 5. "How would it come out according to your estimation if a measurement were made?" When the answers given by the students to this question are examined, the measurements are given by using the symbols of greater (>), smaller (<) and closer (~) so that the measurements are "M" and their own estimates are "E". Here, the estimates accepted in the 5% lower and upper limits of the measurement are considered close.

Table 5. Students comparing their estimates with measurements without measuring

Questions	A*	B*	E**	T**	H***	İ***
Perimeter of the classroom board	M>E	M<E	M<E	M<E	**M>E**	**M~E**
Surface area of teacher desk	**M<E**	M>E	**M>E**	M~E	M<E	**M<E**
Volume of fruit juice for 20 people	M~E	**M>E**	M>E	M~E	**M<E**	**M>E**
Height of basketbol court	M>E	M>E	M>T	M~E	**M>E**	**M<E**
Floor area of basketbol court	**M>E**	**M>E**	**M>E**	**M>E**	**M>E**	**M>E**
Volume of oil for pancake	M~E	**M>E**	**M<E**	M~E	M~E	M>E
Desired length of Turkish flag	**M~E**	M~E	**M~E**	**M~E**	M~E	**M~E**
Volume of syrup in the syrup bottle	M~E	M~E	M~E	**M~E**	M~E	**M~E**
Floor area of the bust	M~E	M~E	M~E	**M~E**	M<E	**M>E**

The students whose comparisons were correct are indicated in Table 5 in bold font and dark background. When the students are examined, three of the comparisons of Asya* and Barış*; while four of Helin***, Tuna** and Eda** were successful, eight of İrfan***'s comparisons were successful. İrfan*** was the most successful student in comparing his estimations with the measurements. İrfan*** was also the student who made the most successful estimates according to Table 4. In other words, this student can be described as a successful student both in estimating the measurements and in self-evaluation. Asya* and Barış*, who have lower estimation success according to Table 5, are also more unsuccessful in evaluating their estimations according to Table 4 without measuring. While the estimation success of Tuna** and Eda** was at a moderate level, their success in evaluating their estimations was also at a moderate level. However, the estimation success of Helin***, which was low among girls and average among all students, was also at a medium level.

When Table 5 is examined in terms of questions, different findings have emerged according to questions. Although not successful in estimating the floor area of the basketball court, all students correctly interpreted that the area of the basketball court would be larger than their estimates. Here, the fact that students are limited to much smaller numbers in the estimation of large areas has an effect, that is, they have difficulty in estimating. However, in other questions, students often incorrectly compared their estimates with the measurements.

In addition, in the questions expected to estimate the volume of the syrup in the syrup bottle and the desired length in the Turkish Flag, all of the students stated that a measurement close to their estimates would be obtained. Estimating here by first looking at the photograph and then touching the objects may have made the students think that their estimates were too close to the measurement. When they examined the object themselves and made an estimate, the students responded with more confidence.

While some of the students' comparisons of the measurements that will be made without measuring with their estimations were correct, some were incorrect. In these comparisons, while some students only used expressions such as "less, more, close, smaller or larger", some students made more detailed explanations. Here are some statements of the students.

Regarding the perimeter of the classroom board, Asya* stated that the perimeter would be more than her estimation since it consists of two parts. Helin*** made the statement: "It could be bigger. Because of the bottom.". Tuna** stated that it could be smaller by saying "It comes out smaller. Because I first said 3 meters, then I said 6 meters, but there is not as much as 6 meters.". İrfan*** said "It will increase by 1 m at most." stating how much difference there could be between the measurement and the estimation.

For the volume of fruit juice, Barış* stated that if the glasses were filled more, the result would be more. While estimating, İrfan*** thought that a glass would be 125 mL or 150 mL, then estimated by chosing 125 mL, and commented "If it were to be measured after the estimation, the glass will come out like 150 mL.".

For the height of the basketball court, while Asya* said, "Probably more truth than mine.", İrfan*** said, "Most likely, it may be low. I don't think it will be high." stating that it might be lower than he expected. Helin*** commented the difference between the possible result and the estimation by saying "May be big, 4 meters or so" for the pitch height, which she estimated at 3.5 m.

For the floor area of the basketball court, "I think it will come out big." Asya* stated that more results will be achieved than the estimation. Barış*, "It will come out high." Tuna** thought that the difference between the measurement and the estimation would be very large by saying "Far.". İrfan*** explained with the help of a detailed example that more results would come out of his estimation by saying "For example, I can go over the house. If we say the house is 100 m^2 on average, it will be quite high."

For the volume of olive oil, İrfan*** said, "It can be bigger. I can't imagine how many mL it is. May be more." With his interpretation, he revealed that he was not very sure about his estimate. For the syrup volume, Tuna** stated that it would be close without much difference by saying "It doesn't matter, it's close to my estimation."

3.3. Findings from Measurements Made after Estimation

For the purpose of the research, students were expected to make measurements in some questions and evaluate their estimations according to these measurements. Findings related to this process are discussed in this chapter.

Measurements were made for the perimeter of the classroom board, the desired length of the Turkish Flag, the volume of juice and syrup, the surface of the teacher's desk and the area of the floor where the Atatürk bust is located. Since it is thought that the length of the basketball court and the size of the court, the olive oil volume may cause pollution in the classroom environment, and the measurement of both the length of the court and the volume of the oil will force the students and lose a lot of time, no post-estimation measurements were made in these questions. In these questions, the measurements were told directly to the students and they were expected to compare the measurements with their estimates.

In order to make measurements, the tools and equipment have been prepared with the necessary alternatives in mind. A calculator is also provided here for students to use. In the research, it was aimed to determine the measurement-based estimation skills and measurements, and since there was no purpose to determine the calculation skills and calculation-based estimation skills, there was no inconvenience in the use of calculators during the measurement. After the measurement was made, the students were allowed to use a calculator and pen and paper in the required four operations. The students were asked to make their own choices for the tools they would use in the measurement, and the tools and materials chosen by the students are shown in Table 6.

Table 6. Tools used during measurement

Questions	Asya*	Barış*	Eda**	Tuna**	Helin***	İrfan***
Perimeter of the classroom board	Meter and calculator					
Volume of fruit juice for 20 people	Pet cup, water bottle ve liquid measuring cup					
Volume of syrup in the syrup bottle	Syrup spoon, syrup ve liquid measuring cup					
Floor area of bust	Meter and calculator					
Desired length of Turkish Flag	Ruler	Ruler	Tape measure	Ruler	Tape measure	Meter
Surface area of teacher table	Meter & calculator	Meter & calculator	Meter & calculator	Meter & calculator	Tape measure & calculator	Meter & calculator

When Table 6 is examined, it is seen that the meter, calculator, liquid measuring cup, syrup bottle, syrup spoon, pet glass and water bottle were used by all students. While the tape measure was used three times in two different questions by Helin*** and Eda**, the ruler was used in one question by Asya*, Tuna** and Barış*. İrfan***, on the other hand, used only meters in all length and area measurements.

It was noticed that the students who were asked to measure in six questions sometimes had difficulties and made mistakes, but no intervention was made until the measurement was completed. In only one question, the measure was directly told to the students. For the syrup volume, each student started to measure with a syrup spoon, but after a few spoons, the students were given the volume information of the syrup due to their difficulties. The values that the students found as a result of the measurement are given in Table 7.

Table 7. The values that the students found after measurement

Questions	Asya*	Barış*	Eda**	Tuna**	Helin***	İrfan***
Perimeter of the classroom board	8.98 m	529 cm	8.7 m	8.90 m	8.94 m	8.90 m
Surface area of teacher table	0.72 m^2	0.72 m^2	0.72 m^2	0.72 m^2	0.72 m^2	0.72 m^2
Volume of fruit juice for 20	2 L	2000 mL	2 L	3.5 L	3.4 L	3 L
Floor area of the bust	79552 cm^2	170 cm	8.75 m^2	79994 cm^2	90368 cm^2	91136 cm^2
Desired length of Turkish Flag	26 cm	26 cm	26 cm	26 cm	26 cm	26 cm

According to Table 7, it is seen that all students reached the same values as a result of the upper surface area of the teacher's desk and the length measurement indicated on the Turkish flag. It is thought that the length of the Turkish Flag and the side lengths of the teacher's desk are small enough for students to measure easily. In addition, it is thought that the fact that the lengths of the side lengths on the upper surface of the teacher's table are zero, with zero digits, may be effective in reaching the result easily. For students who reach new numbers as a result of rounding in some questions, this question has prevented the differentiation in the results, since there are numbers that do not need to be rounded. For this reason, the measurements of all students in this question were the same.

In other questions, it is seen that there are differences between the measurements of the students. With the effect of the difficulties students had in the measurement of large objects, differentiation is also increasing, especially in the questions for the estimation of large objects. In addition, while the students were measuring the edges of the board and the floor where the Atatürk bust was located, they often attempted to round the result. It has also been observed that there are students who get the wrong grades on the numbers they will use to calculate the area. In the measurement of the volume of fruit juice, the differences in the amount seen during the filling of the glass by the students caused the students to reach different results.

Asya*, who used meters to measure the circumference of the classroom board, expressed the length of the subfloor as 172 m, which she found as 172 cm. When asked about the unit, Asya*, who also expresses it in m (meter) after measuring the short side of the board, said, "Meter. Because we've already measured by meter.". Asya*, who was found to have difficulties in calculating the circumference, corrected the unit to centimeters when asked again. After converting the unit to meters appropriately, she compared her estimate with the measurement result, which she found to be more than 8.98 meters, "I found my own estimate as 12. I was sure there would be more." she stated. However, later on, saying "No, it turned out less." she realized that her estimation was less than the measurement result. The fact that this question is the first question for Asya* probably caused excitement, and thus led her spending a lot of time on this question and having too many mistakes.

Barış* ignored one of the sides while measuring to find the perimeter of the classroom board and used different values on the right and left sides, as seen in his statement "340 cm (long side) where I estimate it's 100 (right side). I calculated above at 340+100+89. 529 is the result. Its unit is cm.". Also Barış* said, "I thought not all wood would be made." It was seen that he thought that only one piece of the board would be estimated and that he expressed that there was a great difference between his estimation and measurement.

While Helin*** was measuring, she expressed her confusion by saying "This place is 174.5 cm. But all 342 came out here. That part turned out to be 105. Its circumference is 474 cm". While she was trying to measure one piece first, she also said, "What did I do, I don't understand? Shall I delete it or do it again?". Later, she realized her mistake and calculated the circumference of the board as "894 cm (342+105+342+105 cm)". Comparing the measurement with Helin***'s estimate, she saw that her estimate was a bit far off, saying, "I estimate I just thought of the board only" she explained.

İrfan*** expressed his use of meter to measure the circumference of the classroom board with his statement "Of course, the ruler will remain small. The tape measure will also be small. Meter is best". In the measurement, he reached the result of "340 cm, 105 cm, 445 − 890 cm", and the measurement was close to his estimation by expressing "There is a 90 cm difference. Close."

When Tuna** was shown the instruments that can be used for measurement, he made a choice by saying "It doesn't matter, but meters.", "" He expressed the difference between his measurement and his estimation numerically by saying "My estimate was 6 meters, there is a difference of 3 meters.

Eda** also chose the meter and measured as follows: "3 and a half 3.38 m (height). We can say that this place is 1 m. (With a calculator) 1 m 4 cm, 1 + 3.35 = 4.35, and if we multiply this by 2, it is

8.7 m". She stated the closeness of the measurement result and her estimation by saying "My estimate was relevant, I think".

While measuring the upper surface area of the teacher desk, Helin*** used tape measure while the other students used meter, and all students reached the same result. Asya* thought that the measurement was smaller than her estimation, although Barış* used meter in his estimation, the measurement was low regardless of the unit in the measurement, and Tuna** thought that the measurement was irrelevant with his 3 m estimate. Helin*** stated that her estimation was far from the measurement by saying "Far. I took the long side too small. It was far from what I expected.". Although İrfan***'s estimation was 1.04 m^2, during comparison, he commented that his estimation (remembering as 1.4 m^2) was twice the measurement. Eda** explained that her estimation was irrelevant to the measurement by saying "It's a bit irrelevant. The size was somewhat relevant but the smallest. My estimate was irrelevant."

Some of the dialogues about reaching different results in the volume of 20 cups of juice are included in the explanations. Since the researcher filled the cups to half, she asked Asya* "Do you give it to everyone like this?". She gave the answer "Yes, each cup turned out to be 100 mL. Then it was 20.100= 2000 mL. So 2 liters." and reached the result of 2 L. She stated that her estimation was less than the true value. Asya* found each cup to be 100 mL, as she filled the cups almost halfway. Barış* also filled in the same amount, but found a different result because he made a mistake in the calculation. Barış* who said "A cup of 100 mL would be 1200 mL for 20 people." was reminded of calculator, and then Barış*, like Asya*, reached the result of 2000 mL.

Figure 5. Eda during the measurement of the volume of fruit juice**

When Eda** (See Figure 5) filled the cup close to half like Asya* and Barış* and poured it into the container. She examined it and said "It's a little over 100 mL. If we multiply 100 by 20, it is 2000 mL, which is 2 L.". However, unsure of herself, "Is it really 2 L?" she said, and learned that the result she will find may change according to the fullness of the cup. After learning the result, "50 L. Should I say 50 mL?" she hesitated and estimated the result of the measurement, "It was far." she compared.

Figure 6. Helin during the measurement of the volume of fruit juice**

While Eda**, Asya* and Barış* reached the same result, different results were obtained by other students in the measurement. Helin*** "Shall I put this much?" asked the amount of filling the cup, but since no direction was given by the researcher, she filled it on her own decision (See Figure 6). Then she reached the result of 3.4 L by saying "I think it is less than 200 mL. I'm going to multiply 2 by 170 in a 170 mL cup. 3400 mL = 3.4 L". She compared her estimation with the measurement by saying "Far. I took 100mL very large. Because the width of the cup is small, it is less.". İrfan*** made his measurement as "When we put it like this, 150 ml is the outcome. No need to try 20 times, we will multiply by 20. That is 3000 mL, which is 3 L." and stated that his estimation is close to his measurement by saying "I am close by 500 ml.". Tuna** reached the result of 3.5 L with the operation "175.20= 3500 mL = 3.5 L". The smallest value for the juice volume with different results was 2 L, while the largest value was 3.5 L. The difference in the amount of cup filling of the students was evaluated as the reason for the variation in the results.

Meter, ruler and tape measure were used to measure the length indicated on the Turkish Flag. Despite the use of different tools and equipment, the students reached the same results.

Figure 7. Asya* and Barış* during the measurement of the desired length of the flag

It was also observed that there were students who had problems in using rulers to find the desired length in the flag. Asya* started measuring by holding the ruler starting at 1 (See Figure 7 on the left). When asked about this situation, she corrected her mistake and reached the result of 26 cm by saying "I started from 1. You actually start from scratch". Barış* also wanted to start measuring from the middle of the ruler (See Figure 7 on the right), but when he was asked what time to start, he turned to zero and completed the measurement as 26 cm. When comparing the measurement to the estimate, he stated that he made a closer estimation by looking at the flag itself instead of looking at its photograph by saying "The flag itself made it closer because it was large."

Eda**, who estimated 26 cm from both the photograph and the flag, measured with a tape measure and reached the same result with her predictions. She said that her estimation is the same as the measurement, "I made 26 too, my teacher. It turned out exactly 26." explained in her words.

Helin*** also measured with a tape measure and said, "26 cm is like the middle of my two estimates." she replied by comparing the measurement with his estimates. This difference is "Someone is difficult on small paper. In the other, we do operations by folding. That's why it looks different. Bigger is more comfortable." she commented. Unlike his friends, İrfan*** made measurements with meters, but he reached the same conclusion. By measuring their estimates, "At first, it is 78 cm, so the process is easier in a small area. It's easier than the thumbnail." and emphasized that estimating with a photograph is more comfortable than estimating by looking at the flag. Tuna**, who first took the meter in his hand and then turned to the ruler, said, "It will be more comfortable with this, 26 cm." He also stated that his estimation is very close to the measurement. By looking at the photo and the

original, his estimate is "Looking at the image, I thought there would be two. But looking at the reality, I realized that there would be 3 (comparing E and G). I took 78 as 75 and divided it by three, I said 25." he compared.

All students used meters and calculators to measure the area of the floor where the Atatürk bust was located, but there was much variation in the results. Asya* measured the sides as 352 cm and 226 cm on the floor where the bust was located, and calculated the area as 79552 cm^2. Her estimated measurement is "Mine was 24 thousand. That's a little small." she compared. While Barış* is measuring, he was content to measure only one side and found it enough to say" nearly 170 red areas. When asked "Is this the only measurement?" by the researcher, he finished the measurement with the answer "Yes.".

Helin***, while measuring, expressed the sides as 353 cm and 226 cm, but when writing on paper and in the calculator, she took it as 256 cm instead of 226 cm. This led her to find the result that should have been 79778 cm^2 as 90368 cm^2. Helin***'s post-measurement comment was "My estimations were too small. The initial estimate is smaller in the photo."

İrfan*** mistakenly used 256 cm instead of 226 cm when calculating the edges, which he measured as 356 and 226 cm, like Helin***. It is noteworthy that İrfan*** and Helin*** made the same number of mistakes. In addition, when İrfan*** asked if he could round the numbers while using the numbers in area calculation, when the researcher answered, İrfan*** used the numbers without rounding. It was observed that he neglected some steps while finding the result as 91136 cm^2, converting between units and expressing it as "Exactly 9.1 m^2". When comparing the measurement with the estimates, he said, "I found it easier to estimate than the photograph, as in the flag, because I divided it into lines." He stated that his estimate was closer to the measurement by looking at the photograph instead of looking closely with his explanation. This interpretation of İrfan*** differs from the perspectives of other students.

Eda**, like the others, started to measure with meters, but rounded the results to 2.5 m and 3.5 m. By using the calculator, she stated that the area would be "8.75 m^2.". It is noteworthy that Eda** took notes by rounding the results she found and added it to the operation without consulting the researcher. Tuna** also measured the sides as 227 and 352 cm, then said, "There is a big difference between them, but the second was better than the first. When I saw it, my mind became clear." He stated that the estimation is closer when looked closely with his interpretation.

Since finding the size of the syrup in the syrup bottle was both challenging and causing hygiene problems, the students were told the measurement result directly after a few spoon measurement attempts. When the volume was learned, Asya* said, "It was more. I thought it was close. It's 150 mL. One should not look immediately with the decision of the eye, but should look in more detail." emphasized that one should not make random estimates by eye. Barış* said, "I estimate it was a smaller number than I estimated, but it was bigger than the next estimate. The 2nd estimate was further away." He said, looking at the photograph, that his estimation is closer.

As Helin*** started measuring, "That's it at one time." she showed the cup with her hand and looked at the decreasing amount in the bottle and made a measurement. She made her own estimation, "I made it pretty big here." she criticized. As Eda** fills and pours the syrup into the spoon during the measurement, "It never rises in a spoon. I think it's too much of my answer." made her comment. After learning the size, she said, "My estimate was 65. More than 2 times. I thought a few scoops would reduce the syrup. It decreases very little. The syrup tricked me." She used humorous language while comparing her estimation with the measurement. İrfan *** said, "It was 150 ml. So on average 30 spoons. There is a 30mL difference with what I found." he compared his estimate with the measurement. Tuna** also said, "Not too close, but not too far." he made the comment and compared his estimate with the measurement.

The students were not expected to measure the height of the basketball court, and after the height estimations, the students were told by the researcher. While some of the students stated that the estimates were close to the measurement, some of them said that they were far. Tuna** emphasized that his first estimate was closer by saying "Far. First I said 4m, then I said 5m.". Eda**, on the other hand, was astonished when she heard the height of the court, "Is it really 3.7 m, sir? I thought like this. If my height is 1.5 isn't it higher?" she stated. She continued her explanation and bewilderment by saying "Actually, it seemed high to me. "When I look at it, I say 7 meters. If I'm 1.5".

For the area of the basketball court, the students were not expected to measure, and the real value was told to the students by the researcher after the area estimates. It was observed that there was a difference between the estimates of most students and the actual value in this question, in which some students had confusion in the units and some students estimated length instead of area. Asya* made an estimation by considering the length and the problem she had with the units; "Oh, if I say m, if I say cm, m comes out if I say cm." she stated. Tuna**, "I understand that he is asking for another length, not the area." he stated that he confused the length with the area. Eda** said, "The answer is gone, I'm gone." she stated that her estimation differs greatly from the measurement. Helin***, who thought it was too bad when comparing the measurement with the estimate, said, "Far is too far. I estimate I estimateed from the length of the poles too short." She evaluated her estimate with her statement. Helin*** reminded by the researcher that she is closer in estimating the measurements on the classroom board or the teacher desk, and that it is farther away: "It is a little more difficult to estimate because the basketball court is so long." explained the reason for this situation.

Since the volume of olive oil is difficult to measure and will cause hygiene problems, the students were told by the researcher. While comparing their estimates with the measurement/actual value, some students expressed closeness while others were surprised. Tuna**, "I don't think it's too close or too far" while commenting, Eda** said, "Sir, I thought the volume of oil was more than water." she expressed her surprise with her statement.

By measuring after their estimations, the students had the opportunity to compare their estimations with the measurement and also practiced how to find the dimensions of the objects. Even if erroneous measurements were made from time to time, comparing the measurements with their estimates also gave the students the opportunity to evaluate themselves.

4. DISCUSSION and CONCLUSION

For the purposes of the research, students' estimation skills were examined. Estimates were evaluated with scores ranging from 0% to 200% of the real measurement. Students whose predictions fell outside this range received zero points. Students' estimation skills average 42.18 out of 100 points. It was concluded that while the highest score was 72.50, the lowest score was 24.75. It was found that male students' measurement-based estimation skills were related to their mathematics achievement. Although one of the female students had a high mathematical success, their estimation skill was not at a high level compared to other students. However, it was determined that estimation skills and mathematics achievement levels were compatible in other female students as in male students. The result that the level of mathematics achievement and estimation skills are compatible is consistent with the results of the studies of Çilingir and Türnüklü (2009) and Erdoğan and Erben (2020).

When estimation skills were evaluated according to the sub-dimensions of measurement, it was seen that the highest success was in length estimation. It was determined that the students were more successful in the volume estimation than the area estimation. It is thought that the fact that there are only questions that require estimation of liquid volume in volume estimation reveals that students have higher estimation skills in volume estimation than area estimation. In their study, Kumandaş and Gündüz (2014) concluded that students use their measurement skills in length estimation, but they

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cannot use this skill sufficiently in weight and volume estimation. This shows that there is agreement between the results.

It is also seen that there are students who make estimations with some operations without making a distinction between length, area or volume. Here, it has been revealed that there is a tendency to random estimation, as well as inability to distinguish the sub-dimensions of measurement and there may be deficiencies in the concepts. Tan-Şişman and Aksu (2012) also revealed in their studies that students were more successful in questions based on procedural knowledge, where they were not successful in the questions that required the sub-dimensions and the coordination of these sub-dimensions.

It is striking that there is an intermediate level student who makes estimations by mixing the area and the perimeter. This shows that there is a misconception about environment and space. Dağlı and Peker (2012, p. 344) also revealed in their studies that 5th grade students confuse the calculation of perimeter and area. This shows the agreement between the results.

When the estimation skills of the students were evaluated according to the categories of the questions, the estimation skills of the students reached the highest level when they were asked to make predictions by using the images, that is, by giving photographs and objects in person. The result that students are more successful in making predictions by using visuals is compatible with the result of Boyraz's (2017) study. Among these, while the students made a closer estimation to the measurement when they were near the object, they made a slightly farther estimation from the photograph without seeing the object in person. When students are asked to estimate in cases where they cannot see the object in person or from its photograph, it is seen that their estimation skills remain at the lowest level. Students who were asked to make an estimation of the dimensions of the objects they frequently encounter in daily life made more successful estimations, while they had difficulty in estimating very large or very small objects and exhibited a low level of estimation skill.

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As a sub-problem of the research, after the estimations based on measurement, what the students experienced in the process of comparing their estimations according to the measurements without measuring was examined. Students generally think that the estimates will come close to the measurement. While some of them were thought to be less than the measurement, it was seen that some of them were thought to be larger than the measurement. When asked to make predictions about objects with very large dimensions, it was observed that they thought that the estimates would be smaller than the measurement. This result shows that students do not trust their own estimates if the object sizes are too large.

It was seen that the students were not very successful when they compared their predictions with the real value without measuring. When the students' level of success in comparison was examined, it was concluded that they were successful at a moderate level (48.1 %). It is noteworthy that while students with high estimation success are more successful in comparing estimation with measurement, students with lower estimation skills show lower success in comparing estimation with measurement without measuring. This shows that there is a linear relationship between predictive success and predictive interpretation success and self-efficacy perception. When the students were asked to interpret their predictions, it was seen that their predictions were not very strong. However, it was also noted that students with high estimation skills had stronger predictions about estimation interpretation.

According to the last of the research problems, when the students were asked to make measurements and compare the measurements with the predictions; it was seen that all students used the meter, while some students used the tape measure and ruler. One student, on the other hand, used only the meter while measuring the lengths and did not use the tape measure and ruler. Pet cups, water bottles, syrup spoons, syrup bottles, liquid measuring cups and calculators were used by all students.

When the measurement results of the students are examined, there are questions with very different results. When the measurements of the questions with the same results were examined, measurements of smaller objects or measurements consisting of numbers that did not need rounding were reached. The increase in the dimensions of the objects increases the differentiation in the measurement results of the students. This differentiation was caused by the students' tendency to round the numbers due to student difficulties due to the size of the dimensions and their misuse, excitement and carelessness after the measurement. In the measurement made to find the liquid volume, it was seen that the amount of filling the glass changed the result a lot. Some differences can be seen when the methods used by the students during measuring are examined. In her study where students performed control after making predictions, Kösece (2020) concluded that students used different strategies and diversified their strategies as they continued to make measurements. Also, this study supports the conclusion that it is useful to control estimates by measuring.

In addition to reaching different measurement results, it was observed that students had problems in using units or converting units to each other in estimations and measurements. When students are asked to compare their estimates with the measurement results, it is also seen that some students evaluate the measurement as close to their estimates without paying attention to the units. This result reveals that students have problems with units. In addition, the lack of knowledge in the area and perimeter formulas negatively affects the estimation and measurement skills of the students. The problematic situations about the circumference and area are also encountered in the study of Satan (2020). Some examples of these errors are that there are errors related to student use in the measuring tools, trying to measure by starting from one or a different number instead of zero on the ruler and tape measure, and trying to say the result without taking into account the starting point. Similar examples can be found in the study of Güven-Akdeniz and Argün (2019). This is in line with the finding of Emekli (2001) that students have serious difficulties and misconceptions in measuring readings, calculating perimeter, area and volume.

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When the students were reminded that they could use a calculator whenever necessary during the measurements, it was observed that some students used the calculator in some questions. However, it is noteworthy that some students preferred to make mental operations in some questions. When asked to compare their post-measurement estimates with the measurements, it was noted that some students described the small differences between the estimate and the measurement as large, while some students described the large differences as small or almost ignored them and expressed them as close. Here, it is seen that students with higher estimation skills can distinguish the difference more easily and show higher performance in comparing the measurements with their estimations. Students who are not very successful in estimating and making accurate measurements are also not very successful in comparing measurement and estimation.

Measurement and units are the basis of measurement-based estimation. For this reason, it is thought that students' lack of knowledge about measurement and units affects both their estimation skills and their performance in comparing measurements with estimations.

Recommendations

Depending on the results achieved in this research, some suggestions can be offered to practitioners and researchers. It is recommended to include the estimation skill in the curriculum, course resources and in-class practices. Likewise, it is thought that the inclusion of questions to determine measurement-based estimation skills in central exams will enable students to attach more importance to this subject. While preparing the questions for the research, textbooks and supplementary books were used, but very few questions related to the subject were reached. More questions should be included in textbooks and supplementary books. It is thought that it would be

beneficial for practitioners to use more activities while teaching this subject to students. In addition, after the estimation activities, students should be provided to check their estimations by measuring. It is thought that more time should be devoted to the use of tools and equipment for measurement. Also, more time can be spent teaching the unit conversion topic. In this study, only questions about estimating the liquid volume were included in the volume estimation. A more comprehensive version of this research can be done at different grade levels. It is also among the suggestions to conduct a research on the problems experienced in the use of measurement tools and equipment.

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