



An Examination of Middle School Students' Understanding of the Concepts of Speed and Velocity in the Science Curriculum of the Türkiye Century Education Model

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Abstract

It is important for students to construct concepts in a meaningful way. Knowing the meaning of concepts and being able to identify their relationships with other concepts is crucial for meaningful learning. However, when students learn concepts, they may confuse concepts that are similar but have different content, leading to misconceptions. It is important for students to fully learn concepts so that they can identify the differences between the concepts they have learned and other concepts. In Türkiye, the science curriculum was revised in 2024, and for the first time, the concept of velocity, a vector quantity, was included in the curriculum. Since velocity is a vector quantity, previous curricula only addressed the concept of speed. It is considered important that a new topic is included in the curriculum and that its learning is examined. This study aimed to investigate how middle school students learn the concepts of speed and velocity, and whether they have any potential misconceptions. A measurement tool consisting of four open-ended questions covering the topic of speed and velocity was used as the data collection instrument. The questions were designed to cover the definitions of speed, velocity, displacement, distance traveled, the difference between speed and velocity, and the interpretation of these concepts with examples from daily life. The students' responses were analyzed using content analysis and descriptive statistics. The findings show that students were more successful in questions related to the concept of speed based on daily life; however, they experienced significant difficulties in cases where velocity, displacement, and these concepts were considered together with mathematical relationships. It is particularly noteworthy that the correct answer rates were quite low in questions where velocity, being a vector quantity, needed to be related to the concepts of direction and displacement.

Keywords: Türkiye Century Education Model, Speed and Velocity, Concept Teaching, Misconception

1. Introduction

Science education is one of the fundamental fields that aims to enable individuals to interpret phenomena and events they encounter in daily life based on scientific concepts, to question them, and to acquire effective problem-solving skills. In this context, the Science Curriculum implemented in Turkey is reorganized and updated periodically to strengthen students' scientific process skills and support lasting conceptual learning.

With the changes made in education in 2024, a holistic education approach centered on the student has been adopted in the Science Curriculum. The Science Curriculum aims to cultivate well-rounded individuals who possess the skills required by the age, have a lifelong learning habit, can utilize higher-order thinking and scientific process skills, embrace ethical and moral values, are entrepreneurial, and have a career awareness in the field of science (MEB, 2024). In line with this aim, students are expected to understand fundamental science concepts that they can relate to daily life and to develop scientific process skills. For meaningful learning to occur, students need to align their prior knowledge with new information. This is possible only by teaching fundamental science concepts correctly and completely at an early age (Günaydın, 2010).

The issue of misconceptions in science education has been the subject of numerous studies in Turkey, and it has been observed that most of these studies focus on prospective teachers or high school students (Günaydın, 2010; Ecevit and Özdemir Şimşek, 2016; Balbağ, 2018; Şimşek, Yurtcan and Oktay, 2019; Yolcu, Karamustafaoğlu and Karamustafaoğlu, 2021; Zengin and Bozkurt, 2022; Yıldız, 2022). However, it is seen that the number of studies conducted on students regarding the misconceptions that arise in science teaching, within the context of the currently used curriculum, is quite small, and the need for students to understand and examine these misconceptions has emerged.



1.1. Research Aim and Significance

Not every incorrect answer should be directly identified as a misconception. A systematic process is necessary to identify and correct misconceptions. Determining how misconceptions arise in science lessons can contribute to teachers conducting the teaching process more consciously and planned, and to ensuring lasting learning. This creates a preventive approach to the formation of misconceptions in science, reducing the risk of potential misconceptions and making them a part of the teaching process (Yıldız, 2022). In Türkiye, the science curriculum was renewed in 2024, and the concept of 'speed,' which was not included in previous programs, was included in the curriculum for the first time. The fact that speed is a vector quantity makes the teaching of this concept more complex compared to the concept of velocity, which is addressed only through magnitude. Therefore, this study, which determines how students understand this newly added concept in the curriculum, what misconceptions arise, and what kinds of difficulties are encountered in the learning process, is of great importance in terms of evaluating the effectiveness of the curriculum.

Based on this, the research question was formulated as follows: "What is the level of understanding of the concepts of speed and velocity among 6th grade middle school students within the scope of the Science Curriculum of the 21st Century Türkiye Education Model?"

2. Method

2.1. Research Model

This study is a descriptive survey research using both qualitative and quantitative data. Descriptive research aims to objectively present and analyze the current situation without any intervention. In this approach, the phenomena under investigation are examined in detail, and a systematic description is made by exploring the connections between past data and current conditions (Karakaya, 2014). Accordingly, the aim of this research is to systematically analyze the current situation and examine the relationships between the relevant variables.

2.2. Study Group

The study group consists of a total of 30 6th-grade students studying in the Konak district of Izmir. The study group was determined using a convenient sampling method.

Table 1. Distribution of Students Participating in the Research According to Gender

Gender	f	%
Female	19	% 63
Male	11	% 37
Total	30	100

When Table 1 is examined, it is seen that 63% of the students participating in the research are female (19) and 37% are male (11). The majority of the participants in the research are female students.

2.3. Data Collection Tool

In this study, a measurement tool consisting of four open-ended questions covering the topic of speed and velocity was used as a data collection tool. The questions were prepared to cover the dimensions of definition of speed, definition of velocity, displacement, definition of distance traveled, the difference between speed and velocity, and the interpretation of these concepts with examples from daily life. The measurement tool was submitted to the opinions of experts in the field [science teachers / academics] to ensure content validity, and necessary adjustments were made.

2.4. Data Analysis

The students' responses were analyzed using content analysis and descriptive statistics. The analysis process was carried out in the following stages:

1. Student responses were examined individually.



2. Responses were coded under four categories: correct, incorrect, partially correct, and blank.
3. Coding was done independently by two researchers, and the inter-coder agreement percentage was calculated for reliability. Data analysis was performed separately by two field experts. The reliability formula suggested by Miles and Huberman (1994) was used to calculate the reliability of the research. When calculating the agreement percentage, the number of agreeing codes was divided by the total number of codes and multiplied by 100 to obtain the agreement percentage ($9/11 \times 100 = 81\%$). Reliability calculations above 70% are considered reliable for the research (Miles and Huberman, 1994; Cited in: Baltacı, 2017).
4. Frequency (f) values were determined for each question.
5. The misconceptions held by the students were identified by examining the incorrect answers. The findings obtained were presented in tables and interpreted.

3. Findings

This section presents the findings obtained from the measurement tools applied to determine the knowledge levels of middle school students regarding the concepts of speed and velocity. The students' responses were evaluated under the categories of correct-incorrect, partially correct, and blank; frequency (f) values were calculated for each question and presented in a table.

3.1. The Findings Obtained for Question 1 are Presented Below:

Table 2. Evaluation Criteria and Response Categories for Question 1

Question 1	Criteria
<p>The image is taken from a vehicle.</p>  <p>What does this image represent?</p>	<p>Correct statements:</p> <ul style="list-style-type: none"> -If it clearly states that the image is a speedometer and indicates the vehicle's speed -If it states that the vehicle is traveling at 90 km/h <p>Partially correct statements:</p> <ul style="list-style-type: none"> -It shows how fast it's going. -Speedometer <p>Incorrect statements:</p> <ul style="list-style-type: none"> -It shows the vehicle's mileage. -It shows the fuel level. • Irrelevant answer

Table 3. Distribution of Students' Answers to Question 1

Questions	True (f)	Partially True (f)	False (f)	Blank (f)	Total
Question 1	11	14	5	0	30

Table 3 shows the distribution of students' answers regarding the image taken from the vehicle in Question 1. According to the table, 11 students correctly interpreted the image. These students stated that the image was a speedometer and represented the vehicle's speed. 14 students gave partially correct answers. This group of students stated that the image "shows how fast the vehicle is going" or that it was a "speedometer," but they did not explicitly use the concept of speed or specify a unit. Five students gave incorrect answers. These students interpreted the image as an indicator showing the vehicle's mileage or fuel level, or gave irrelevant explanations.

Some of the students' correct answers to Question 1 are as follows:

- S2: 'It expresses speed.'
- S3: 'It expresses the kilometer and speed setting. (It expresses speed.)'
- S9: 'The speed of the vehicle.'
- S21: 'Speed.'

Some of the students' partially correct answers to Question 1 are as follows:

- S1: 'This image shows the speed of the car.'
- S8: 'This image shows the speed of a vehicle in hours.'
- S14: 'How fast it is going.'

Some of the students' incorrect answers to Question 1 are as follows:

- S11: 'This image represents the gasoline poured into the car.'
- S 20: 'The kilometer shows 85.'



S 13: 'It expresses kilometers and hectometers.'

3.2. The Findings for Question 2 are Presented Below:

Table 4. Evaluation Criteria and Response Categories for Question 2

Question 2	Criteria
<p>Fatma and Mustafa, who live in the same apartment building, set off early in the morning on their bicycles to go to school. The school was very close to home. Fatma said she needed to stop at the stationery store first, and they left the front of their house at the same time. Fatma went the 500-meter route while Mustafa went the 200-meter route. Fatma and Mustafa moved at a constant speed throughout the journey. Surprisingly, they arrived at school at the same time. Mustafa asked, "You went to the stationery store and came the long way, how did we manage to be here at the same time?" Both were very happy that they weren't late for class.</p> <p>a) Write down the reason why Fatma, despite taking the longer route, arrived at school at the same time as Mustafa. b) Compare the distances Fatma and Mustafa traveled. c) Rank the distances Fatma and Mustafa traveled from greatest to least. d) Write down what can be said about Fatma and Mustafa's speeds.</p> <p>Correct statements: a) <input type="checkbox"/> If he/she states that Fatma's speed is greater than Mustafa's. If he/she says that Fatma's speed is greater because she covered a greater distance in the same amount of time. b) <input type="checkbox"/> Fatma = Mustafa. If they state that the displacement is related to the starting and ending points. If they indicate that Fatma and Mustafa start from the same place and arrive at the same place. Therefore, if they say that their displacements are equal. c) <input type="checkbox"/> If it indicates that Fatma traveled more distance than Mustafa. If it gives the correct order: Fatma > Mustafa. If it expresses it using numerical values or the correct symbol. d) <input type="checkbox"/> Fatma= Mustafa (They are equal because their displacements are the same in the same amount of time). If he/she states that Fatma and Mustafa's displacements are the same, he/she uses the information that they arrived at school in the same amount of time. Therefore, he says that their speeds are equal.</p>	<p>Partially correct statements: a) Fatma went faster. She uses everyday language like "fast" but doesn't explicitly specify the concept of speed. b) If they say "Their displacements are the same" without specifying why, they arrive at the correct conclusion but lack a conceptual explanation. If they only write the result without mentioning the concept of path c) If they say Fatma has made more progress but don't explicitly write the ranking. If they only use verbal expressions, without using comparison symbols. d) If he/she says, "Their speeds are the same," without providing a reason, she will arrive at the correct conclusion but will not use the definition of speed.</p> <p>Incorrect statements: a) <input type="checkbox"/> Fatma's speed is greater. Their speeds are different. b) <input type="checkbox"/> If he/she confuses displacement with distance traveled. If he/she says that Fatma's displacement is greater. If he/she says, "Fatma's displacement is greater because she traveled a longer distance." c) <input type="checkbox"/> If he/she says Mustafa has traveled further. If he/she makes the wrong order: Mustafa > Fatma. If he/she confuses the concept of distance with displacement d) <input type="checkbox"/> If he/she says, "Fatma's speed is greater," If he/she relates speed to the distance traveled, If he/she confuses the concepts of speed and velocity <input type="checkbox"/> Irrelevant answer</p>

Table 5. Distribution of Students' Answers to Question 2

Questions	True (f)	Partially True (f)	False (f)	Blank (f)	Total	
Question 2	a	2	6	19	3	30
	b	3	5	21	1	30
	c	13	10	7	0	30
	d	1	14	25	0	30

Table 5 shows that in Question 2a, 2 students reached the correct answer. 6 students gave partially correct answers, while 19 students gave incorrect answers. 3 students left this sub-question blank. This distribution indicates that students had difficulty using the concept of speed correctly when explaining why Fatma arrived at school in the same amount of time despite traveling a longer distance.

For Question 2b, 3 students gave the correct answer, and 5 gave partially correct answers. 21 students gave incorrect answers, and 1 student left the question blank. In this sub-question, it is observed that the majority of answers confused the concept of displacement with the concept of distance traveled.



In sub-question 2c, the correct answer rate is higher compared to other sub-questions. Thirteen students answered correctly, while 10 answered partially correctly. Seven students answered incorrectly, and there were no blank answers. This finding indicates that students are more successful in comparing and ranking the concept of distance traveled.

Examining question 2d, however, the number of students who answered correctly is quite low. Only one student answered correctly, while 14 students answered partially correctly. Twenty-five students answered incorrectly, and there were no blank answers in this sub-question. This distribution reveals that students have difficulty explaining the concept of speed within the framework of the relationship between displacement and time.

Here are some of the **correct answers** students gave to Question 2:

For "a"; S2: 'Fatma's speed is greater.' S15: 'Because Fatma went faster.'	For "b"; S25: 'Fatma = Mustafa. Fatma and Mustafa have moved the same distance from each other.' S6: 'Fatma = Mustafa. Because both of them went from home to school.'
For "c"; S3: 'Fatma traveled more distance than Mustafa. Fatma traveled 500 meters while Mustafa traveled 200 meters. Mustafa traveled less distance.' S14: 'Fatma 500 Mustafa 200, Fatma > Mustafa'	For "d"; S22: 'Their velocities are the same. That is, their displacements per unit time are the same.'

Here are some of the students' **partially correct answers** to Question 2:

For "a"; S7: 'Fatma caught up quickly because she went faster.' S9: 'Fatma arrived faster.'	For "b"; S1: 'Their positions are the same' S9: 'They are both the same.'
For "c"; S20: 'Fatma has traveled more distance. Mustafa has traveled less distance.' S27: 'Fatma is 500 meters tall, Mustafa is 200 meters short.'	For "d"; S12: 'Fatma and Mustafa have equal speeds.' S15: 'They both moved at a constant speed.'

Here are some of the **incorrect answers** students gave to Question 2:

For "a"; S5: 'Mustafa's house was 300 m closer to the school.' S27: 'It could be km.'	For "b"; S7: 'More' S10: 'Fatma has come a long way.'
For "c"; S18: '200m, 500m' S25: '500<200'	For "d"; S1: 'Fatma is faster than Mustafa' S5: 'Fatma rode the bike slower, but she could have ridden faster.'

3.3. The Findings for Question 3 are Presented Below:

Table 6. Evaluation Criteria and Response Categories for Question 3

Question 3	Criteria
<p>Vehicles K and L, starting simultaneously from points A and C, meet at point B after 2 hours.</p> <p>Accordingly;</p> <p>a) What is the speed of vehicle K in km/h?</p> <p>b) What is the distance between B and C in km?</p>	<p>Correct statements:</p> <p>a) <input type="checkbox"/> If it uses the relationship Speed = Distance / Time, and correctly writes the result as 160 km/h.</p> <p>b) <input type="checkbox"/> If vehicle L moves for 2 hours, and then performs the calculation $120 \text{ km/h} \times 2\text{h}$, it will arrive at a result of 240 km.</p> <p>Partially correct statements:</p> <p>a) If they write the correct formula but make a calculation error. If the numerical result is very close to the correct one but doesn't specify the unit. If they correctly calculate the speed but don't show the calculation step.</p> <p>b) If it sets up the correct operation but makes a calculation error. If it writes the correct result but doesn't specify the unit. If it reaches the result but</p>



	doesn't show the step of the operation. Incorrect statements: a) <input type="checkbox"/> If he/she takes the wrong route (if he/she operates at 120 km/h). If he/she does not take the time into account. b) <input type="checkbox"/> If it calculates the wrong range (confuses A with B). If it uses data from instrument K. If it ignores time information. <input type="checkbox"/> Irrelevant answer
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Table 7. Distribution of Students' Answers to Question 3

Questions	True (f)	Partially True (f)	False (f)	Blank (f)	Total
Question 3					
a	6	2	21	1	30
b	3	1	24	2	30

When Table 7 is examined, in Question 3(a), the calculation of the speed of vehicle K was requested. 6 students answered correctly, 2 students answered partially correctly, 21 students answered incorrectly, and 1 student left the question blank. This indicates that students have difficulty establishing the time-distance-speed relationship in speed calculations. It appears that students who answered partially correctly experienced mathematical errors or deficiencies in specifying units, even though they initiated the necessary calculations.

In Question 3(b), the calculation of the distance between B and C was requested. 3 students answered correctly, 1 student answered partially correctly, 24 students answered incorrectly, and 2 students left this option blank. The high rate of incorrect answers in this option is noteworthy. This reveals that students have conceptual deficiencies in interpreting reciprocal motion and distances covered in the same amount of time.

Here are some of the **correct answers** students gave to Question 3:

For "a"; S9: ' $320:2 = 160 \text{ km/h.}$ ' S2: ' $320:2 = 160 \text{ km/h. The speed of vehicle K is } 160 \text{ km/h.}$ '	For "b"; S9: ' $120 \times 2 = 240 \text{ km}$ ' S3: ' $120 \times 2 = 240 \text{ 240 km}$ '
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Here are some of the students' **partially correct answers** to Question 3:

For "a"; S7: ' 160 km/h ' S4: ' $320:2=120 \text{ km/h}$ '	For "b"; S7: ' 240 km '
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Here are some of the incorrect answers students gave to Question 3:

For "a"; S30: ' $It \text{ is } 320 \text{ km.}$ ' S18: ' $It \text{ is moving } 320 \text{ km in the north direction.}$ '	For "b"; S11: ' $120 \text{ kilometers between B and C}$ ' S16: ' $320-120=200 \text{ km}$ '
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3.4. The findings for Question 4 are presented below:

Table 8. Evaluation Criteria and Answer Categories for Question 4

Question 4	Criteria
Ayşe walks at a constant speed first to the grocery store 2 km east of her house. Then she turns around and walks at a constant speed to the park 1 km west. Ayşe's entire walk takes 1 hour. Answer the questions based on this information. a) Write down the distance Ayşe traveled and her change of position during her movement in the table.	Correct statements: a) <input type="checkbox"/> If he/she writes that the distance covered is 3 km. If he/she indicates that the displacement is 1 km to the east. b) <input type="checkbox"/> If he/she uses the phrase "distance covered," and specifies that it is 3 km. c) <input type="checkbox"/> If it correctly calculates the speed as 3 km/h d) <input type="checkbox"/> If he/she says the displacement is 1 km to the east. Calculate the magnitude of the speed as 1 km/h and specify



Distance Covered (km)	Displacement (km)	
		the direction (east). Partially correct statements: a) If the distance traveled is correct but the displacement is not specified by direction. For example, if he/she only says "1 km". b) If he/she says "distance" but does not specify which road. For example, if it only says "3 km". c) If the numerical value is correct but the unit is not specified. For example, if he/she says "3" or "3 km". d) If the magnitude of the speed is correct but the direction is not specified. For example, if the direction is correct but the magnitude is not specified.
		Incorrect statements: a) <input type="checkbox"/> If he/she confuses the distance traveled with the displacement. If he/she writes the displacement as 3 km. If he/she gives the wrong direction. b) <input type="checkbox"/> If he/she says displacement is used, if he/she says "1 km". c) <input type="checkbox"/> If he/she says 1 km/h d) <input type="checkbox"/> If he/she says the speed is 3 km/h. If he/she confuses speed with velocity. If he/she gives the wrong direction. <input type="checkbox"/> Irrelevant answer

Table 9. Distribution of Students' Answers to Question 4

Questions		True (f)	Partially True (f)	False (f)	Blank (f)	Total
Question 4	a	5	17	5	3	30
	b	4	3	19	4	30
	c	1	2	22	5	30
	d	3	8	13	6	30

When Table 9 is examined, in question 4(a), students were asked to write down the concepts of distance traveled and displacement in the table. In this section, 5 students answered correctly, 17 students answered partially correctly, 5 students answered incorrectly, and 3 students left the question blank. It is observed that the rate of partially correct answers is high.

In question 4(b), students were asked which distance should be used in calculating speed. 4 students answered correctly, 3 students answered partially correctly, 19 students answered incorrectly, and 4 students left this section blank. It is observed that the rate of incorrect answers is remarkably high in this section.

In question 4(c), students were asked to make an inference about Ayşe's speed. In this section, 1 student answered correctly, 2 students answered partially correctly, 22 students answered incorrectly, and 5 students left the question blank. The total rate of incorrect and blank answers is quite high in this section. In question 4, part (d), students were asked to make inferences about the magnitude and direction of velocity. Three students answered correctly, eight students answered partially correctly, thirteen students answered incorrectly, and six students left the question blank.

Here are some of the **correct answers** students gave to Question 4:

For "a"; S25: '3 km, 1 km east' S14: '3 km, 1 km east'	For "b"; S8: 'The distance traveled' S6: 'The distance traveled is divided by the time for the speed.'
For c; S2: '3 km/h'	For "d"; S6: 'Direction = east. Magnitude = 1 km.' S14: 'Magnitude = 1 km. Direction = east.'

Here are some of the students' **partially correct answers** to Question 4:



For "a"; S17: '3, 1' S28: '3, 1 km'	For "b"; S2: '2 km and 1 km' S17: 'We add 2 km and 1 km'
For "c"; S14: 'It is 3 km.' S16: 'Ayşe reached a speed of 3 k.'	For "d"; S25: 'Ayşe's speed is in the eastward direction.' S18: 'She can go fast and from the east.'

Here are some of the **incorrect answers** students gave to Question 4:

For "a"; S26: '1 km, 1 hour' S10: '1 km, 3 km'	For "b"; S25: 'Distance from the grocery store to the park and from the house to the grocery store.' S16: 'Calculated at a speed of 2 km/h.'
For "c"; S3: 'It changed position twice.' S13: 'It traveled at a constant speed.'	For "d"; S4: 'Ayşe makes her journey even longer by turning, and it takes 1 hour.' S21: 'Towards the west'

4. Results and Discussion

This research examined the understanding levels of 6th-grade middle school students regarding the concepts of speed and velocity within the scope of the Türkiye Century of Education Model Science Curriculum. The findings show that students are more successful in questions related to the concept of speed based on daily life; however, they experience significant difficulties in situations where velocity, displacement, and these concepts are considered together with mathematical relationships. It is noteworthy that the correct answer rates are quite low, especially in questions where velocity is a vector quantity and needs to be related to the concepts of direction and displacement. This situation reveals that students learn the concepts at a superficial level and have difficulty gaining conceptual depth. A similar result was obtained in Balbağ's (2018) study, which revealed the cognitive structures of science teacher candidates regarding the concepts of speed and velocity through a word association test and identified their misconceptions. It was determined that teacher candidates had more non-scientific or superficial knowledge about the concept of speed and more misconceptions about the concept of velocity. At the same time, the research results are consistent with Yıldız et al. this is also consistent with the study conducted by (2007), which investigated the thoughts of students studying in the Science Education program and who had taken a mechanics course about speed, constant speed, velocity, acceleration, displacement and distance, and determined their level of understanding.

The research results show that the most common misconceptions students encounter are: using speed and velocity interchangeably, confusing displacement with distance traveled, and failing to establish mathematically correct relationships between speed, time, and distance. In contrast, the higher rates of correct and partially correct answers in questions that only require comparing distance traveled indicate that students can more easily understand situations expressed with concrete and numerical data.

Accordingly, it can be said that simply providing definitional information is insufficient in teaching the concepts of speed and velocity; these concepts should be supported with examples from daily life and visual-motion-based activities, along with variables such as displacement, direction, and time. Furthermore, incorporating more open-ended questions that reveal students' misconceptions in the teaching process is important for supporting conceptual learning. In this context, it is believed that addressing the topics of speed and velocity in science lessons with an interdisciplinary approach, particularly by linking them to mathematical skills, will strengthen students' conceptual understanding.

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