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Eighth Grade Students' Metaphorical Perceptions of Ordered Pair and Variable Concepts

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Abstract

In this study, it was aimed to determine the metaphorical perceptions of eighth grade students regarding the concepts of ordered pair and variable, and to examine the changes in these perceptions according to gender and socioeconomic status. "Phenomenology" design, one of the qualitative research methods, was used as the research model. The sample of the study consists of 400 eighth grade students studying in four public secondary schools of a province in the Black Sea Region in the 2021-2022 academic year and selected by maximum variation sampling method. Metaphoric Perception Form (MPF) was used as a data collection tool. Content analysis was used to analyze the student metaphors related to the concepts. Chi-Square test was used to examine the change of the developed metaphors according to gender and socioeconomic status. According to the findings of the study, the metaphors related to the concept of ordered pair were grouped under 17 conceptual categories and the metaphors of *friend*, *buddy*, *sibling*, *school desk*, *twins*, *pattern* and *close friends* were mostly used. The metaphors related to the concept of variable were grouped under 10 conceptual categories and the most common metaphors were *human*, *emotion*, *chameleon*, *dollar*, *weather forecast*, *life*, *decision* and *foreigner*. While female students developed more metaphors than male students regarding the concepts of ordered pair and variable, male students used more metaphor drawings than female students. For these concepts, secondary schools with high socioeconomic status developed more metaphors than secondary schools with low socioeconomic status.

Keywords: Metaphor, ordered pair, variable, socioeconomic status

Sıralı İkili ve Değişken Kavramlarına İlişkin Sekizinci Sınıf Öğrencilerinin Metaforik Algıları

Öz

Bu araştırmada, sekizinci sınıf öğrencilerinin sıralı ikili ve değişken kavramlarına ilişkin metaforik algılarının belirlenmesi, cinsiyet ve sosyoekonomik düzeye göre bu algılardaki değişimlerin incelenmesi amaçlanmıştır. Araştırma modeli olarak, nitel araştırma yöntemlerinden "olgubilim (fenomenoloji)" deseni kullanılmıştır. Araştırmanın örneklemini, 2021-2022 eğitim öğretim yılı Karadeniz Bölgesi'ndeki bir ilimizin dört devlet ortaokulunda öğrenim görmekte olan ve maksimum çeşitlilik örnekleme yöntemiyle seçilmiş 400 sekizinci sınıf öğrencisi oluşturmaktadır. Veri toplama aracı olarak Metaforik Algı Formu (MAF) kullanılmıştır. Kavramlara ilişkin öğrenci metaforlarının çözümlenmesinde içerik analizi kullanılmıştır. Geliştirilen metaforların cinsiyete ve sosyoekonomik düzeye göre değişiminin incelenmesi için Ki-Kare testi kullanılmıştır. Araştırmanın bulgularına göre, sıralı ikili kavramına ilişkin metaforlar 17 kavramsal kategori altında toplanmış ve en çok *arkadaş*, *kanka*, *kardeş*, *okul sırası*, *ikizler*, *örüntü* ve *yakın arkadaş* metaforları kullanılmıştır. Değişken kavramına ilişkin metaforlar 10 kavramsal kategori altında toplanmış ve en çok *insan*, *duygu*, *bukalemun*, *dolar*, *hava durumu*, *hayat*, *karar* ve *yabancı* metaforları kullanılmıştır. Sıralı ikili ve değişken kavramlarına ilişkin kız öğrenciler, erkek öğrencilere oranla daha fazla metafor geliştirirken, erkek öğrenciler kız öğrencilere göre daha fazla metafor çizimi kullanmıştır. Bu kavramlara ilişkin, yüksek sosyoekonomik düzeye sahip ortaokullar, düşük sosyoekonomik düzeye sahip ortaokullara oranla daha fazla metafor geliştirmişlerdir.

Anahtar kelimeler: Metafor, sıralı ikili, değişken, sosyoekonomik düzey

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INTRODUCTION

Scientific innovations and technological developments in the world also shape teaching. Mathematics itself, which is the source of all scientific fields, prepares the ground for these changes. Where there are many changes, the methods and tools used in mathematics teaching also necessitate change. According to Hanson (1993), metaphors have become one of the transmission tools of teaching in terms of making the teaching process active with instruments such as imagination, different perspective and high motivation and making the student a part of the process.

Metaphors are one of the most effective tools to determine an individual's perspective and attitude towards a concept or to reveal his/her mistakes and misconceptions on any subject (Erdem & Satır, 2000; Sanchez et al., 2000). Metaphors guide individuals in examining what they think and how they feel about any concept and in analysing their perceptions in depth (Yalçın, 2012). Metaphor is an effort to understand a phenomenon with another phenomenon, to experience it with another concept and to bring a different perspective to phenomena (Lakoff & Johnson, 2005). Metaphor contributes to establishing a relationship and strengthening the mental map by reflecting a mental schema on another mental schema (Saban, 2009). It covers the processes of associating the objects or situations we are trying to understand with objects or situations belonging to another field of meaning. Thus, it reveals the overlooked aspects of the concept with a different perspective (Taylor, 1984). With different definitions, metaphor is the expression and often concretisation of a concept with little known properties by establishing a similarity between a concept with little known properties and another concept with well-known properties (Ocak & Gündüz, 2006; Uyan-Dur, 2016). Metaphors are not only structures consisting of analogies, but also a part of the thinking system of the mind (Cerit, 2006). Metaphors have a shaping effect on our language and accordingly on our emotions, thoughts and the way we express ourselves (Morgan, 1998). On the other hand, metaphors contribute to the determination of individuals' attitudes and perspectives towards a phenomenon, and to obtaining, interpreting, sharing and sharing data for this purpose and revealing ambiguous points (Erdem & Satır, 2000).

Metaphors are used in teaching abstract and complex mathematical concepts and revealing their reflections on students. How the student perceives the components of the course from his/her own perspective and what images he/she creates for the concepts in the course are revealed through metaphors (Güveli et al., 2011). Concepts, facts, objects and developments in the environment create perceptions in individuals. With these perceptions, the individual determines his/her feelings, thoughts and attitudes towards a concept or object (Kenç, 2019). In this case, an individual's perception of something is a variable worth examining in terms of revealing his/her attitude towards that thing and showing his/her thoughts. It is of great importance to determine the existing perceptions towards an important course such as mathematics or mathematical terms that encompasses life in every aspect.

Using metaphor is an activity of creating mental models. Mental models, which are a network of meaningful relationships between bits of information, are dynamic structures that improve students' problem solving skills and mathematical thinking (Lai, 2013). Metaphors are tools that develop imagination and intuition and enable students to learn by exploring (Fraser, 2000; Hanson, 1993; Sanchez et al., 2000). In addition, they are mental mechanisms that make a high contribution to the processes of storing and retrieving information in memory. Metaphors are tools that can be used to convey mathematical concepts indirectly due to the abstract structure of mathematics (İşçi, 2019). Metaphors have a great role in learning and memorising concepts that are difficult to learn (Arslan & Bayrakçı, 2006) and making comparisons between concepts (Çelikten, 2005). Comprehension of an unknown thing with more known things through metaphors has popularised the use of metaphors in scientific fields. Scientists have used metaphors to conceptualise scientific phenomena that are difficult to understand in disciplines such as physics and chemistry. For example, the atomic model was conceptualised with the metaphor of ‘plum pudding’ due to its similarity in shape (Schoch, 1983).

In addition to supporting students' cognitive characteristics, metaphors also support their affective characteristics. According to Fraser (2000), metaphors have aspects of developing and improving emotions and intuitions. Alkan and Ertem (2003) stated that mathematics is seen as a difficult and boring course. As a result of the abstract nature of mathematics and accumulated prejudices, students have problems in forming their own concepts and have a negative attitude towards mathematics. At this point, metaphors contribute positively to the affective characteristics of students, increase student motivation, and eliminate fear and reluctance towards the lesson (Fretzin, 2001; Osborn, 1997; as cited in Uysal, 2016). According to Fretzin (2001), increasing student

attitude and motivation through concretisation activities based on the similarities between the objects in the physical environment and the concept being taught are the advantages of using metaphors (cited in Uysal, 2016).

Each metaphor bears traces of the life of the person who creates it. Creating a metaphor is giving a new identity to a concept and this process of giving identity is realised by blending individuals' past experiences, their own mental activities and intellectual identities (Büyükbayram, 2004). The way mathematical terms or concepts are perceived by students is also considered valuable in terms of presenting the meanings that students attribute to these concepts. In line with this idea, many studies have been conducted to reveal how mathematical concepts are perceived by students or teachers. Reeder et al. (2009), in his study in which he determined pre-service teachers' beliefs about mathematics through metaphors, stated that pre-service teachers mostly associated mathematics with the concepts of "development", "travelling" and "production". Güveli et al. (2011) revealed the perceptions of prospective primary school teachers towards the concept of mathematics through metaphors. Accordingly, pre-service primary school teachers produced metaphors mostly in the categories of 'mathematics as an exciting course' and 'mathematics as a difficult and boring course'. Satmaz (2016) tried to determine the perceptions of gifted students towards Science and Art Centre (SAC) and mathematics through metaphors. The most common metaphors for SAC were 'safe and relaxing environment', 'source and transmitter of knowledge', 'developer and guide'. For the concept of mathematics, metaphors were mostly developed in the categories of 'necessary for life' and 'fun'. Kenç (2019) examined eighth grade students' metaphorical perceptions of mathematics and mathematics teachers. It was determined that students developed negative attitudes towards this course with the metaphors they produced such as 'a challenging course' and 'a boring course'. It was determined that students developed positive attitudes towards mathematics teachers with the metaphors they produced such as 'fun' and 'source of happiness'. Ergöl and Sezgin-Memnun (2020) examined the perceptions of fifth and seventh grade students towards the concept of fraction through metaphors and stated that students mostly used 'cake/pizza' and 'knife/scissors' metaphors. In addition, it was concluded that students had difficulty in making sense of the fraction concept and the use of abstract metaphors for the fraction concept increased as the grade level increased.

Algebraic thinking, which represents a special form of mathematical thinking, is an important thinking system that includes problem solving, reasoning, critical thinking and the ability to express a situation with different representations (Çelik, 2007). Algebraic thinking is a thinking system that includes proportional reasoning, understanding variables, analysing relationships between quantities, using models, providing solutions to problems encountered in daily life, making logical inferences and reasoning skills (Greenes & Findell, 1998; National Council of Teachers of Mathematics [NCTM], 2000). Starting from primary school, the concept of pattern is included in arithmetic and geometry, and students are tried to be prepared for algebra teaching (Ministry of National Education [MoNE], 2018). The fact that the foundation of the skills that will make advanced mathematics learning more effective for students, who are expected to gain mathematical abstraction skills gradually, begins to be laid in primary school reveals the role of algebraic thinking in the development of mathematical thinking. In this respect, it is important to determine students' perceptions about the concepts in linear equations belonging to algebra learning area. According to Kabael and Tanışlı (2010), the skills to be used in the sub-learning domain based on the concept of function and function knowledge should be acquired before high school mathematics education. Therefore, this study will provide insight into the readiness of students who will enter high school the following year to learn topics such as functions and analytical geometry, which involve intense abstraction, and will provide insights from their past mathematical life. In addition, student perceptions of mathematical concepts differ according to the gender variable (Doğan & Sönmez, 2019). It is also known that socioeconomic status has an effect on students' mathematics achievement (Yüksel & Ertürk, 2023).

In the literature, there are metaphor studies conducted with primary and high school students, prospective teachers, teachers and administrators. In this context, the participants' perceptions towards mathematical concepts such as whole number, fraction, pattern, set and their perceptions towards mathematics course, teaching and teacher were tried to be determined through metaphors (Ada, 2013; Berber & Sezgin-Memnun, 2018; Cerit, 2006; Çenberci et al, 2020; Çetinsoy, 2019; Ergöl & Sezgin-Memnun, 2020; Güner, 2013a; 2013b; Güveli et al., 2011; Kenç, 2019; M. Taşdemir & F. Taşdemir, 2017; Noyes, 2006; Ocak & Gündüz, 2006; Polat, 2010; Saban, 2009; Sezgin-Memnun, 2015; Soydan, 2021; Yıldırım, 2019). Since there is no study in the literature that reveals the metaphorical perceptions of eighth grade students towards the linear equations sub-learning domain, it is thought that this study will contribute to the literature.

The aim of this study is to determine the metaphorical perceptions of eighth grade students about the concepts of ordered pair and variable, which play an important role in linear equations. In addition, it is to

determine the level of differentiation of metaphor ratios developed according to gender and socioeconomic status. In line with this purpose, answers to the following problems were sought:

1. What are the metaphorical perceptions of eighth grade students regarding the concepts of ordered pair and variable?
2. Do the metaphors and metaphor drawing ratios developed for the concepts of ordered pair and variable differ according to gender?
3. Do the metaphors developed for the concepts of ordered pairs and variables differ according to the socioeconomic status?

METHOD

Research Design

In this study, the "phenomenology" design, one of the qualitative research methods, was used. Phenomenology provides the opportunity to reveal the meanings that individuals attribute to concepts, to examine the way they experience phenomena and their consciousness structures (Moran, 2000). In this study, the "phenomenology" design was used to reveal how the students structure the ordered pair and variable concepts in their minds and how their individual perceptions about these concepts are through metaphors.

Study Group

The study group of the research consists of 400 eighth grade students studying in four public secondary schools of a province in the Black Sea Region of Turkey in the 2021-2022 academic year and selected by maximum variation sampling method. Maximum variation sampling is used for the limited sample group to reflect the universe and present rich situations (Patton, 2014; Yıldırım & Şimşek, 2016). The maximum variation sampling method provides convenience in revealing and comparing the experiences of students studying in different learning environments. In this study, secondary schools in neighborhoods where students with different socioeconomic status live were selected to maximize the reflection of variation. The codes A, B, C and D were given to the secondary schools to be studied.

To determine the socioeconomic status of the schools, firstly, opinions were obtained from the District Directorate of National Education, where the research was conducted, and the administrators of the schools. Secondly, to make the socioeconomic status more effective in line with the opinions received from the institutions, the survey data applied by the school advisory teachers to determine the socioeconomic status of the students were analyzed. In the survey data, the monthly incomes of the parents were discussed. The monthly family incomes of all students participating in the study were listed as a list and then their arithmetic average was taken. Then, the school-based evaluation was started, and the monthly family incomes were listed for each school and their arithmetic averages were calculated separately. By taking the average of the family income of all students participating in the research as a criterion, schools above this average were categorized as secondary schools with *high* and *higher* socioeconomic status, and secondary schools with lower socioeconomic status were categorized as secondary schools with *low* and *lower socioeconomic* status.

Table 1. Socioeconomic Status of Schools

School	Socioeconomic Status
A	School with higher socioeconomic status (ĤSS)
B	School with a high socioeconomic status (HSS)
C	School with a low socioeconomic status (LSS)
D	School with a lower socioeconomic status (ĹSS)

Table 1 provides information about the socioeconomic status of the four secondary schools. Accordingly, A secondary school has higher, B secondary school has high, C secondary school has low and D secondary school has lower socioeconomic status.

Table 2. Information about Participants in Schools

	ĤSS		HSS		LSS		ĹSS		Total	
	f	%	f	%	f	%	f	%	f	%
Female	58	14.50	72	18.00	48	12.00	25	6.25	203	50.75
Male	54	13.50	62	15.50	57	14.25	24	6.00	197	49.25
Total	112	28.00	134	33.50	105	26.25	49	12.25	400	100

According to Table 2, 50.75% of the participants were female and 49.25% were male. 112 students from ĤSS, 134 students from HSS, 105 students from LSS and 49 students from ĹSS participated in the study.

Data Collection Tool

In this study, Metaphorical Perception Form (MPF) was used as a data collection tool. The form consists of fill-in-the-blank sentences "The ordered pair is like … because…" and "The variable is like … because…". At the same time, a drawing box was added under each open-ended question item. Drawing boxes were added in order to closely examine the students' ability to support the metaphors they developed with drawings and their processes of reducing abstract mathematical concepts to concrete. A pilot study of the data collection tool was conducted before the application. The pilot study was conducted with 54 students in four different public secondary schools, which were not included in the main study. After the necessary corrections were made as a result of the pilot study, the implementation phase started.

Data Collection and Implementation Process

The students were asked to create metaphors about the concepts of ordered pair and variable and to make explanations about the metaphor they created with the expression "because". In addition, in the drawing box under each question item, students were asked to describe the developed metaphor through drawing. During the application, the students were informed about the metaphors and examples of metaphors prepared before and outside the research topic were presented. The students were informed that the research would be used only for scientific purposes and therefore the information would not be shared with anyone else. Then, MPF was distributed to the students on a voluntary basis. The instructions written on the form were explained to the students again. In the application phase, the students were kept in the classroom during the application in order to prevent them from being influenced by each other while creating metaphors and to clarify the points that could not be understood. The implementation period lasted one lesson hour (40 minutes).

Data Analysis

Content analysis was used to analyze the metaphors created for the concepts of ordered pair and variable through MPF. Content analysis is the quantification of written or verbal information through coding, systematic grouping of texts into small sub-units and interpretation of data through inference (Balcı, 2005; Bilgin, 2000; Büyüköztürk et al., 2018). The metaphors created by the students for the concepts of ordered pair and variable were analyzed in five stages. These are coding and extracting the data, creating the metaphor list, developing categories, ensuring validity and reliability, and transferring the data to the computer environment (Saban, 2009). Chi-square test was used to examine the variation of the developed metaphors according to gender and socioeconomic status. The significance level was taken as .05 for the applied Chi-Square test.

In this stage, while examining the relationship between socioeconomic status and the rate of metaphor development, schools with high status (ĤSS and HSS) were grouped within themselves and categorized as *high socioeconomic* status and schools with low status (LSS and ĹSS) were categorized as *low socioeconomic* status.

Coding and extracting data: The forms collected from the students were classified by giving symbolic letters as A, B, C, D according to the school's name. In order to have easy access to the analyzed forms, each student form was given a code. For example, when the forms of the students in secondary school A were sorted randomly, the form of the female student in the 3rd place was coded as AK3.

When the student forms were examined, the items that could not form valid metaphor for the concepts of ordered pair or variable, left the explanation part of the metaphor starting with "because" blank, or could not establish a connection between the metaphor and the explanation sentence were excluded from the analysis. 244 forms for the concept of ordered pair and 186 forms for the concepts of variable were not taken into consideration.

Creating a list of metaphors: After eliminating the data that did not form metaphors, metaphor lists for the concepts of ordered pair and variable were created and the metaphors were arranged in alphabetical order. A total

of 86 different metaphors were developed for the concept of ordered pair and 115 different metaphors were developed for the concept of variable. The data in each student form were added to the metaphor tables via Microsoft Office Excel 2019 program.

Identifying the categories: The explanation sentences of the listed metaphors starting with "because" were carefully analyzed to understand which idea was reflected by the metaphor. Each valid metaphor was given codes reflecting its explanation. The researcher grouped the codes belonging to the metaphors in a way to reveal the similarities within themselves and divided these groups into conceptual categories that would best represent them.

The metaphors created for the concept of ordered pair in four secondary schools were divided into 17 conceptual categories. From the category in which the most metaphors were developed to the category in which the least metaphors were developed, the following categories were formed: "Sequentiality", "Togetherness", "Duality", "Relationship with Number Two", "Associating with Notation/Expression", "Specifying a Location", "Sequential and Binary", "Relating to Contrast/Difference", "Linear Relationship", "Specifying a Point", "Negative Attitude", "Determining Position with Axes", "Relating to Similarity", "Rule Hosting", " Connotation", "Associating with Repetition" and "Other". The metaphors created for the concept of variable were divided into 10 conceptual categories and listed from the category with the highest number of metaphors to the category with the lowest number of metaphors as "Variable Belonging to Live/Living", "Inanimate/Inanimate Variable", "Relating to the Unknown", "Symbolic Notation", "Negative Attitude", "Two Option Variables", "Relating to the Infinite", "Condition of Equation", "Using the Meaning of Similar" and "Other".

Ensuring validity and reliability: The metaphor lists and categorization processes for both concepts are given in detail in the findings section. In addition, expert opinion was consulted to confirm the compatibility of the created metaphors with the conceptual categories determined by the researcher. A faculty member in the Department of Elementary Mathematics Teaching was given the lists of metaphors and the categories created for the two concepts. The expert was asked to match the metaphors with the categories determined in a way not to leave the given metaphors open. The agreement of the expert and the researcher was calculated using Miles and Huberman's (1994) formula (Reliability = agreement / agreement + disagreement). Reliability shows that if the agreement percentage is above 0.70, it is at a sufficient level, and if it is above 0.90, it is at the desired level in qualitative studies (as cited in Küçükyılmaz & Duban, 2006). The percentage of agreement was 0.91 for the concept of ordered pair and 0.94 for the concept of variable.

Transferring data to computer environment: As the last step of the data analysis, the metaphors created for the two concepts and the categories determined were transferred to the computer environment as tables.

Research Ethics

First, ethics committee permission was obtained for the research. Then, the necessary permissions were obtained from the national education directorate of the relevant province to carry out the application in the selected schools. The research was conducted on a voluntary basis. Participants were informed about the purpose of the research, and it was stated that the data obtained would be protected within the limits of scientific ethics.

FINDINGS

Findings Related to the First Research Problem

In this section, the findings related to the problem *"What are the metaphorical perceptions of eighth grade students regarding the concepts of ordered pair and variable?"* are presented. The analysis of students' metaphorical perceptions of the concepts of ordered pair and variable is presented.

Findings on the concept of ordered pair: The metaphors, frequencies and percentages of metaphors created for the concept of ordered pair are given in Table 3.

Table 3. Metaphors Developed for the Concept of Ordered Pair

Metaphor	(f)	(%)	Metaphor	(f)	(%)	Metaphor	(f)	(%)
friend	13	8.33	bead	1	0.64	match scores	1	0.64
buddy	9	5.77	large number	1	0.64	market prices	1	0.64
sibling	9	5.77	object	1	0.64	table number	1	0.64
school desk	7	4.49	study	1	0.64	negative person	1	0.64
twins	6	3.85	the multiplication table	1	0.64	bus seat	1	0.64

pattern	6	3.85	double digit numbers	1	0.64	number in parentheses	1	0.64
close friend	6	3.85	fraternal twins	1	0.64	compass	1	0.64
fellow	4	2.56	farmer	1	0.64	vegetables and fruit	1	0.64
number	4	2.56	mountain	1	0.64	Sefer and Volkan Teachers	1	0.64
human	3	1.92	behavior and consequence	1	0.64	class rank	1	0.64
location	3	1.92	marriage	1	0.64	ranking	1	0.64
navigation	3	1.92	F-16	1	0.64	water	1	0.64
desk mate	3	1.92	planet	1	0.64	signboard	1	0.64
cabinet	2	1.28	rainbow	1	0.64	chart	1	0.64
friendship and enmity	2	1.28	daytime and night	1	0.64	Taha and Yigit	1	0.64
apple	2	1.28	dreams and realities	1	0.64	recipe ingredient	1	0.64
day	2	1.28	life	1	0.64	stew meal	1	0.64
good and evil	2	1.28	life challenge	1	0.64	wagon and tractor	1	0.64
digits	2	1.28	goal setting step	1	0.64	destination	1	0.64
student at school desk	2	1.28	two humans	1	0.64	letter y	1	0.64
Achilles and Patroclus	1	0.64	two-wheeled motorcycle	1	0.64	foreign	1	0.64
forgive	1	0.64	reduplication	1	0.64	side-by-side items	1	0.64
Ahmet Kural and Murat Cemcir	1	0.64	doing the work	1	0.64	jigsaw	1	0.64
family	1	0.64	miss	1	0.64	half heart	1	0.64
key issue	1	0.64	melon and watermelon	1	0.64	contestant	1	0.64
atom	1	0.64	combo	1	0.64	top three in competition	1	0.64
Bilge and me	1	0.64	north and south pole	1	0.64	food and coke	1	0.64
killing two birds with one stone	1	0.64	labyrinth	1	0.64	egg box	1	0.64
complete each other	1	0.64	l labut	1	0.64			
						total	156	100

When the metaphor frequency table in Table 3 is analyzed, the most common metaphors developed were *friend* (f=13), *buddy* (f=9), *sibling* (f=9), *school desk* (f=7), *twins* (f=6), *pattern* (f= 6), *close friend* (f=6), *fellow* (f=4) and *number* (f=4). It was observed that 86 different metaphors were developed for the concept of ordered pair and 156 (39.00%) of the 400 students who participated in the application were able to create valid metaphors. Although 11 (2.75%) students were able to create metaphors, they left the explanation part starting with "because" blank, and 27 (6.75%) students could not express the common relationship between the subject of the metaphor and its source, that is, the metaphors they developed, and the explanation part were incompatible. In addition, 206 (51.50%) students left the item blank in which they were asked to develop metaphors for the concept of ordered pair.

Table 4. Distribution of Metaphors Developed for the Concept of Ordered Pair by Schools

	ĤSS		HSS		LSS		ĹSS	
	f	%	f	%	f	%	f	%
Valid Metaphor	57	50.89	56	41.79	25	23.81	18	36.73

When the frequencies of metaphor development according to schools are analyzed in Table 4, it is observed that 57 (50.89%) students in ĤSS, 56 (41.79%) in HSS, 25 (23.81%) in LSS and 18 (36.73%) in ĹSS were able to create valid metaphors.

Table 5. Distribution of Metaphor Drawings for the Concept of Ordered Pair

	Students using metaphor drawing		Students not using metaphor drawing		Total	
	f	%	f	%	f	%
Student	98	62.82	58	37.18	156	100

According to Table 5, 98 (62.82%) of the students who created valid metaphors for the concept of ordered pair expressed their metaphors with drawings, while 58 (37.18%) did not use drawing to explain their metaphors. The student metaphors created for the concept of ordered pair were analyzed separately for each of the four secondary schools and these metaphors were analyzed and divided into conceptual categories.

Table 6. Conceptual Categories Related to the Concept of Ordered Pair

Category	Number of Metaphors (f)	Percentage (%)	Category	Number of Metaphors (f)	Percentage (%)
Sequentially	32	20.51	Specifying a Point	5	3.21
Togetherness	25	16.03	Negative Attitude	5	3.21
Duality	20	12.82	Determining Position with Axes	3	1.92
Relationship with Number Two	15	9.62	Relating to Similarity	3	1.92
Associating with Notation/Expression	10	6.41	Rule Hosting	2	1.28
Specifying a Location	9	5.77	Connotation	2	1.28
Sequential and Binary	7	4.49	Associating with Repetition	1	0.64
Relating to Contrast/Difference	6	3.85	Other	5	3.21
Linear Relationship	6	3.85			
			Total	156	100

In Table 6, the metaphors developed for the concept of ordered pair are divided into 17 conceptual categories. Students developed the most metaphors in the category of "Sequentiality" (20.51%; f=32). Afterwards, it was observed that students developed many metaphors in the categories of "Togetherness" (16,03%; f=25), "Duality" (12,82%; f=20), and "Relationship with Number Two" (9,62%; f=15), respectively. Below, the distribution of metaphors in the conceptual categories related to the concept of ordered pair according to socioeconomic status is given by creating frequency and percentage tables:

Table 7. Metaphors and Student Statements Developed in the Category of Sequentially

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Sequentiality	Buddy (3), pattern (2), key issue (1), rainbow (1), top three in competition (1), labout (1), behavior and consequence (1)	Day (2), planet (1), miss (1), bead (1), wagon and tractor (1), object (1), pattern (1), goal setting step (1), sibling (1)	Human (2), number (2), close friend (1), the multiplication table (1), twins (1)	Digits (2), bus seat (1), ranking (1), friend (1)	32	20.51

According to Table 7, 24 different metaphors were developed by 32 students in the category of "Sequentiality" and the concept of ordered pair was most associated with the metaphors of *buddy* (f=3) and *pattern* (f=3). Some student statements are as follows:

AE84: "The ordered pair is like a pattern, because it is sequential like a pattern."

BE10: "The ordered pair is like a day, because it goes on sequentially."

CK68: "The ordered pair is like a twin, because they are born one after the other."

DK15: "The ordered pair is like digits, because digits come in sequential order."

Table 8. Metaphors and Student Statements Developed in the Togetherness Category

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Togetherness	Buddy (3), fellow (2), family (1), complete each other (1), friend (1), Bilge and me (1), close friend (1)	Friend (4), sibling (3), fellow (2), jigsaw (1), close friend (1), school desk (1), human (1), daytime and night (1), half heart (1)	-	-	25	16.03

In Table 8, 13 different metaphors were developed by ĤSS and HSS students (f=25) in the category of "Togetherness" and the concept of ordered pair was associated with the metaphors of friend (f=5) and fellow (f=4)

the most. LSS and ĹSS students did not develop metaphors in this category. Some student statements are as follows:

AK8: "The ordered pair is like a buddy, because they never separate from each other."

BK130: "The ordered pair is like a jigsaw, because they don't mean anything on their own, but together they are complete."

BK78: "The ordered pair is like a sibling, because they complement each other harmoniously."

BK89: "The ordered pair is like a fellow, because they have meaning when they are side by side."

Table 9. Metaphors and Student Statements Developed in the Duality Category

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Duality	Sibling (2), Taha and Yigit (1), twins (1)	Friend (3), buddy (2), combo (1), Sefer and Volkan teachers (1), Achilles and Pacrollus (1), Ahmet Kural and Murat Cemcir (1)	Friend (1)	School desk (2), close friend (1), friend (1), contestant (1), side-by-side items (1)	20	12.82

According to Table 9, 14 different metaphors were developed by 20 students in the category of "Duality" and the concept of ordered pair was mostly associated with the metaphor of *friend* (f=5). Some student statements are as follows:

BK28: "The ordered pair is like Ahmet Kural and Murat Cemcir, because they are together in most projects."

BK66: "The ordered pair is like Achilles and Pacrollus, because they are inseparable characters in the game."

DE21: "The ordered pair is like a contestant, because each contestant forms a group of 2 for themselves."

DK10: "The ordered pair is like a school desk, because we sit in pairs."

Table 10. Metaphors and Student Statements Developed in the Category of Relationship with Number Two

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Relationship with Number Two	close friend (1), two-wheeled motorcycle (1)	Apple (2), twins (1), student at school desk (1), lettery (1)	Cabinet (2), chart (1), forgive (1)	Desk mate (2), school desk (2)	15	9.62

In Table 10, 11 different metaphors were developed by 15 students in the category of "Relationship with Number Two" and the metaphors of *apple* (f=2), *cabinet* (f=2), *desk mate* (f=2) and *school desk* (f=2) were used the most. Other metaphors were repeated only once. Some student statements are as follows:

BK63: "The ordered pair is like a student in a school desk, because two people sit in the desk."

BE83: "The ordered pair is like an apple, because it's like two parts of an apple."

CK10: "The ordered pair is like a cabinet, because it has two side surfaces."

CK16: "The ordered pair is like forgiveness, because it is like forgiving a person twice."

Table 11. Metaphors and Student Statements Developed in the Category of Association with Notation/Expression

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Associating with Notation/Expression	Table number (1), market prices (1), fraternal twins (1), friend (1), large number (1), friendship and enmity (1), two humans (1), close friend (1)	-	Foreign (1), number in parentheses (1)	-	10	6.41

According to Table 11, 10 different metaphors were developed by ĤSS and LSS students in the category of "Association with Notation/Expression" and each metaphor was repeated only once. HSS and ĹSS students did not develop metaphors in this category. Some student statements are as follows:

AE2: "The ordered pair is like the table number, because the table sequence numbers are like 0,1."

AE60: "The ordered pair is like market prices, because there are fractional numbers like 4.3 all the time."

AK54: "The ordered pair is like a close friend, because there is a black cat between close friends and a comma between the ordered pair."

AK41: "The ordered pair is like friendship and enmity, because one can be positive while the other can be negative, both can be positive and both can be negative."

Table 12. Metaphors and Student Statements Developed in the Category of Specifying a Location

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Specifying a Location	Location (3), F-16 (1), compass (1), signboard (1)	Navigation (1), student at school desk (1)	-	Navigation (1)	9	5.77

According to Table 12, seven different metaphors were developed by nine students in the "Specifying a Location" category. In this category, the concept of ordered pair was mostly associated with the metaphor of *location* (f=3). Other metaphors were repeated only once. LSS students did not develop any metaphor in this category. Some student statements are as follows:

AK35: "The ordered pair is like a compass, because we can move according to them and find our place in the country."

AK58: "The ordered pair is like a signboard, because it shows where we are."

AE4: "The ordered pair is like the F-16, because we enter the positions, and it looks like the same ordered pair."

DK30: "The ordered pair is like a navigation, because it reports location."

Table 13. Metaphors and Student Statements Developed in the Category of Sequential and Binary

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Sequential and Binary	Match scores (1)	Class rank (1), twins (1), food and coke (1)	Egg box (1), desk mate (1)	Double digit numbers (1)	7	4.49

According to Table 13, seven different metaphors were developed in the category of "Sequential and Binary" and each metaphor was repeated only once. Some student statements are as follows:

AK38: "The ordered pair is like match scores, because two numbers next to each other remind me of matches."

BE112: "The ordered pair is like twins, because they are born sequentially and in pairs."

CK46: "The ordered pair is like an egg box, because it is ordered and arranged in pairs."

DE43: "The ordered pair is like double digit numbers, because they are in pairs and in order."

Table 14. Metaphors and Student Statements Developed in the Category of Relating to Contrast/Difference

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Relating to Contrast/Difference	-	Dreams and realities (1), sibling (1), negative person (1), vegetable and fruit (1), melon and watermelon (1), north and south pole (1)	-	-	6	3.85

According to Table 14, six different metaphors were developed by HSS students in the category of "Relating to Contrast/Difference". Some student statements are as follows:

BK95: "The ordered pair is like dreams and realities, because dreams are plus and realities are minus."

BE93: "The ordered pair is like a sibling, because they are either opposites or partners."

BE127: "The ordered pair is like a vegetable and a fruit, because they are opposites."

BE122: "The ordered pair is like a melon and a watermelon, because they are both different fruits."

Table 15. Metaphors and Student Statements Developed in the Category of Linear Relationship

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Linear Relationship	Farmer (1), doing the work (1), killing two birds with one stone (1)	Pattern (1)	Study (1), water (1)	-	6	3.85

According to Table 15, six different metaphors were developed in the category of "Linear Relationship" and each metaphor was repeated only once. ĹSS students did not develop any metaphor in this category. Some student statements are as follows:

AE23: "The ordered pair is like a farmer, because the better he looks after his field, the better the results."

AK25: "The ordered pair is like doing the work, *because the more tomatoes you plant, the more tomato paste you make."*

BE84: "The ordered pair is like pattern, because it goes at a certain rate."

CE51: "The ordered pair is like, because if you go in the right direction, you'll succeed."

Table 16. Metaphors and Student Statements Developed in the Category of Specifying a Point

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Specifying a Point	Destination (1), recipe ingredient (1), sibling (1), buddy (1)	-	-	Navigation (1)	5	3.21

In Table 16, five different metaphors were developed in the category of "Specifying a Point". HSS and LSS students did not develop metaphors in this category. Some student statements are as follows:

AK9: "The ordered pair is like a destination, because the ordered pair indicates a point to be reached."

AK55: "The ordered pair is like a sibling, because even though they are far, far away, they always meet at a common point."

DE5: "The ordered pair is like a navigation, because it too points to a destination."

Table 17. Metaphors and Student Statements Developed in the Negative Attitude Category

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Negative Attitude	Life challenge (1), stew meal (1)	-	Number (2), labyrinth (1)	-	5	3.21

According to Table 17, four different metaphors related to the concept of ordered pair in the "Negative Attitude" category were developed by five students. The metaphor of *number* (f=2) was used the most. HSS and ĹSS students did not develop any metaphor in this category. Some student statements are as follows:

AK111: "The ordered pair is like a stew meal, because it is complicated."

AE48: "The ordered pair is like the difficulty of life, because you struggle, you cannot solve it, you get exhausted."

CK29: "The ordered pair is like a labyrinth, *because it's so complicated."*

CE52: "The ordered pair is like a number, because it is very difficult when you get it wrong."

Table 18. Metaphors and Student Statements Developed in Other Categories

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Determining Position with Axes	Marriage (1), mountain (1), good and evil (1)	-	-	-	3	1.92
Relating to Similarity	Twins (1)	Twins (1), sibling (1)	-	-	3	1.92
Rule Hosting	-	Pattern (2)	-	-	2	1.28
Connotation	-	-	School desk (2)	-	2	1.28
Associating with Repetition	-	Life (1)	-	-	1	0.64
Other	Reduplication (1), friendship and enmity (1), good and evil (1)	-	Atom (1), friend (1)	-	5	3.21

One student statement for each category given in Table 18 is given below respectively:

AE47: "The ordered pair is like a marriage, because the sum of the two is the result of the marriage. The abscissa is male and the ordinate is female because it is the ordinate that will raise the marriage."

BK46: "The ordered pair is like a sibling, because the first sister or brother is born, then the brother or sister is born and they are similar to each other."

BE79: "The ordered pair is like a pattern, because it follows a rule."

CE31: "The ordered pair is like a queue, because its name starts in order."

BE31: "The ordered pair is like a life, because it consists of repeating occurrences."

CE105: "The ordered pair is like a atom, because the speed and position of the atom cannot be known at the same time, the uncertainty principle."

Considering the tables explaining the conceptual categories, the metaphors developed for the concept of ordered pair were divided into 13 conceptual categories in ĤSS, 11 in HSS, 9 in LSS and 6 in ĹSS. The categories of "Sequentiality", "Duality", "Relationship with Number Two", "Sequential and Binary" are common categories created in all four secondary schools.

Findings on the concept of variable: The metaphors, metaphor frequencies and metaphor percentages for the concept of variable are given in the table below.

Table 19. Metaphors Developed for the Concept of Variable

Metaphor	(f)	(%)	Metaphor	(f)	(%)	Metaphor	(f)	(%)
human	37	17.29	flag	1	0.47	ID number	1	0.47
emotion	11	5.14	indefinite work	1	0.47	person without identity	1	0.47
chameleon	8	3.74	uniqueness	1	0.47	book page	1	0.47
dollar	5	2.34	information	1	0.47	subject	1	0.47
weather forecast	5	2.34	individual	1	0.47	bad person	1	0.47
life	5	2.34	stock exchange	1	0.47	KPSS score	1	0.47
decision	5	2.34	Buse	1	0.47	rule	1	0.47
foreigner	5	2.34	alive	1	0.47	LGS	1	0.47
hair	4	1.87	spy	1	0.47	math teacher	1	0.47
friend	3	1.40	corpse	1	0.47	spoilsport kid	1	0.47
thought	3	1.40	gender	1	0.47	school	1	0.47
day	3	1.40	effort	1	0.47	leek	1	0.47
name	3	1.40	environment	1	0.47	pastry	1	0.47
personality	3	1.40	strawberry	1	0.47	problem solving	1	0.47
mum	2	0.93	detective	1	0.47	psychology	1	0.47
car part	2	0.93	pilot test	1	0.47	puzzle	1	0.47
perspective	2	0.93	tv series	1	0.47	president republic	1	0.47
me	2	0.93	DNA	1	0.47	colour	1	0.47
letter	2	0.93	colors in nature	1	0.47	clock	1	0.47
bet coupon	2	0.93	world	1	0.47	looking for a needle in a haystack	1	0.47
hypocrite human	2	0.93	economy	1	0.47	number	1	0.47
head	2	0.93	idea	1	0.47	love	1	0.47
mood	2	0.93	the future	1	0.47	beloved	1	0.47
passing class	2	0.93	development	1	0.47	class	1	0.47
secret	2	0.93	mysterious human	1	0.47	question mark	1	0.47
liquid substance	2	0.93	security	1	0.47	water	1	0.47
x symbol	2	0.93	sun	1	0.47	suspicious	1	0.47
brother	1	0.47	teacher	1	0.47	swap	1	0.47
adaption	1	0.47	habit	1	0.47	telephone battery	1	0.47
agent	1	0.47	possibility	1	0.47	phone password	1	0.47
mind	1	0.47	two faces of man	1	0.47	horizon line	1	0.47
hour and minute hands	1	0.47	request	1	0.47	product	1	0.47
gold	1	0.47	black sea people	1	0.47	liar	1	0.47
mum's dinner	1	0.47	character	1	0.47	aging	1	0.47
car	1	0.47	characterless person	1	0.47	meal	1	0.47
car battery	1	0.47	indecision	1	0.47	path	1	0.47
factious human	1	0.47	fight	1	0.47	face	1	0.47

sunflower	1	0.47	melon seeds	1	0.47			
mirror	1	0.47	cake	1	0.47			
						total	214	100

When the metaphor frequency table in Table 19 is analysed, the most common metaphors developed were *human* (f=37), *emotion* (f=11), *chameleon* (f=8), *dollar* (f=5), *weather forecast* (f=5), *life* (f=5), *decision* (f=5), *foreigner* (f=5) and *hair* (f=4). It was observed that 115 different metaphors were developed for the concept of variable and 214 (53,50%) of the 400 students who were applied were able to create valid metaphors. In addition, it was observed that 13 (3,25%) students could create metaphors but left the explanation part starting with "because" blank, and 21 (5,25%) students could not express the common relationship between the subject of the metaphor and its source, that is, the metaphors they developed, and the explanation part were incompatible. In addition, 152 (38,00%) students left the item blank in which they were asked to develop a metaphor for the concept of variable.

Table 20. Distribution of Metaphors Developed for the Concept of Variable by Schools

	ĤSS		HSS		LSS		ĹSS	
	f	%	f	%	f	%	f	%
Valid Metaphor	72	64.29	68	50.75	44	41.90	30	61.22

When the frequencies of metaphor development according to schools are analyzed in Table 20, it is observed that 72 (64,29%) students in ĤSS, 68 (50,75%) students in HSS, 44 (41,90%) students in LSS and 30 (61,22%) students in ĹSS were able to create valid metaphors.

Table 21. Distribution of Metaphor Drawings for the Concept of Variable

	Student Using Metaphor Drawing		Student Not Using Metaphor Drawing		Total	
	f	%	f	%	f	%
Student	110	51.40	104	48.60	214	100

According to Table 21, 110 (51.40%) students who created valid metaphors for the concept of variable used metaphor drawings, while 104 (48.60%) students did not use metaphor drawings. The student metaphors created for the concept of variable were analyzed separately for each of the four secondary schools and were divided into conceptual categories through metaphor analyses.

Table 22. Conceptual Categories Related to the Concept of Variable

Category	Number of Metaphors (f)	Percentage (%)	Category	Number of Metaphors (f)	Percentage (%)
Variable Belonging to Live/Living	109	50.93	Two Option Variables	4	1.87
Inanimate/Inanimate Variable	51	23.83	Relating to the Infinite	2	0.93
Relating to the Unknown	31	14.49	Condition of Equation	1	0.47
Symbolic Notation	7	3.27	Using the Meaning of Similar	1	0.47
Negative Attitude	6	2.80	Other	2	0.93
			Total	214	100

In Table 22, the metaphors developed for the concept of variable were divided into 10 conceptual categories. The students developed the most metaphors in the category of “Variable Belonging to Living/Living” (50,93%; f=109). Afterwards, it was observed that students developed many metaphors in the categories of “Inanimate/Inanimate Variable” (23,83%; f=51) and “Relating to the Unknown” (14,49%; f=31), respectively. Below, the distribution of metaphors included in the conceptual categories related to the concept of variable according to socioeconomic status is given by creating frequency and percentage tables:

Table 23. Metaphors and Student Statements Developed in the Category of Variable Belonging to Live/Living

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
	Human (5), emotion (4), decision (3), perspective (2), hypocrite human (2),	Human (10), emotion (5), friend (3), chameleon (2), life (2), decision (1), me (1),	Human (7), chameleon (6), name (3), alive (1), strawberry	Human (8), hair (2), mind (1), face (1), thought (1),		

Variable Belonging to Live/Living	personality (2), foreigner (1), liar (1), brother (1), habit (1), life (1), individual (1), adaptation (1), Black Sea people (1), path (1), mother (1), effort (1), spoilsport kid (1), Buse (1), teacher (1), bad person (1)	development (1), request (1), mood (1), hair (1), thought (1), math teacher (1), beloved (1), sunflower (1), hour and minute hands (1), idea (1), characterless person (1)	(1), two faces of man (1), head (1), character (1), mood (1)	emotion (1), psychology (1), class (1), indecision (1), personality (1), aging (1)	109	50.93

According to Table 23, 46 different metaphors were developed by 109 students in the category of "Variable Belonging to Live/Living". In this category, the concept of variable was mostly associated with the metaphors of *human* (f=30), *emotion* (f=10) and *chameleon* (f=8). Some student statements are as follows:

AK35: "The variable is like the Black Sea people, because their feelings change very quickly."

AK32: "The variable is like an individual, because the numbers that replace those variables resemble that each individual is different."

DK17: "The variable is like an thought, because when you first see a person, you see them as a good person or a bad person. As you get to know that person, your thoughts change."

DK20: "The variable is like psychology, because people's psychology can change a lot during the day."

Table 24. Metaphors and Student Statements Developed in the Category of Inanimate/Inanimate Variable

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Inanimate/Inanimate Variable	Weather forecast (2), flag (1), economy (1), meal (1), stock exchange (1), dollar (1), liquid substance (1), rule (1), information (1), book page (1), phone password (1), car battery (1), pilot test (1), product (1), KPSS score (1), environment (1)	Dollar (3), bet coupon (2), colors in nature (1), mirror (1), telephone battery (1), water (1), gold (1), weather forecast (1), pastry (1), day (1), TV series (1)	Car part (2), passing class (2), mum's dinner (1), car (1), sun (1), cake (1), subject (1), school (1), color (1), liquid substance (1)	Day (2), weather forecast (2), world (1), number (1), life (1), clock (1)	51	23.83

According to Table 24, 39 different metaphors were developed by 51 students in the category of "Inanimate/Inanimate Variable". In this category, the concept of variable was mostly associated with the metaphors of *weather forecast* (f=5), *dollar* (f=4) and *day* (f=3). Some student statements are as follows:

AE34: "The variable is like weather forecast because the weather varies as sunny, cloudy and windy."

AE16: "The variable is like the dollar, because the dollar fluctuates a lot in our country."

AK9: "The variable is like meal, because if an ingredient changes, the result changes. (3,4) fried potatoes, (3,2) boiled potatoes."

CE5: "The variable is like cake, because we can change the ingredients whenever we want."

CE105: "The variable is like a liquid substance because like a liquid, it takes the shape of the container it is in."

Table 25. Metaphors and Student Statements Developed in the Category of Relating to the Unknown

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Relating to the Unknown	X symbol (2), human (2), future (1), agent (1), detective (1), question mark (1), DNA (1), corpse (1), secret (1), melon seeds (1), problem solving (1), indefinite work (1), foreigner (1), decision (1)	Human (3), security (1), mysterious human (1), secret (1), life (1), foreigner (1), dollar (1), spy (1), suspicious (1)	Emotion (1), person without identity (1)	Mum (1), thought (1)	31	14.49

According to Table 25, 23 different metaphors were developed by 31 students in the category of "Relating to the Unknown". In this category, *human* (f=5) metaphor was used the most. Some student statements are as follows:

AK65: "The variable is like DNA, because when there are reciprocal chains where DNA is not repaired, it is not known which one, A-T or S-G, cannot match."

BK104: "The variable is like a spy, because it takes effort to find out what it is."

BE90: "The variable is like a dollar, because you never know what will happen when."

DE28: "The variable is like a thought, because you cannot know what a person is thinking."

Table 26. Metaphors and Student Statements Developed in the Category of Symbolic Notation

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Symbolic Notation	Foreigner (2), uniqueness (1), human (1)	Factious human (1)	Letter (2)	-	7	3.27

According to Table 26, five different metaphors in the "Symbolic Notation" category were developed by seven students. In this category, *foreigner* (f=2) and *letter* (f=2) metaphors were mostly used. ĹSS students did not develop any metaphor in this category. Some student statements are as follows:

AE108: "The variable is like a human, because people are different because they are different, like x and y."

CE83: "The variable is like a letter because x, y, z are letters and variables are also letters."

BK75: "The variable is like factious human, because in math's, letters come between numbers and numbers are separated from each other."

Table 27. Metaphors and Student Statements Developed in the Negative Attitude Category

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Negative Attitude	Me (1)	-	LGS (1), leek (1), puzzle (1), hair (1), looking for a needle in a haystack (1)	-	6	2.80

According to Table 27, six different metaphors were developed in the "Negative Attitude" category. HSS and ĹSS students did not develop metaphors in this category. Some student statements are as follows:

CK41: "The variable is like a puzzle, because I try but I cannot find it."

CK46: "The variable is like hair, because I cannot find it even if we comb it, that is, even if we try to solve it."

CE9: "The variable is like looking for a needle in a haystack because it is very difficult to find."

CE19: "The variable is like leek, because I don't like it at all."

Table 28. Metaphors and Student Statements Developed in Other Categories

Category	ĤSS (f)	HSS (f)	LSS (f)	ĹSS (f)	f	%
Two Option Variables	-	President republic (1), fight (1), head (1), gender (1)	-	-	4	1.87
Relating to the Infinite	Possibility (1)	Horizon line (1)	-	-	2	0.93
Condition of Equation	-	Love (1)	-	-	1	0.47
Using the Meaning of Similar	-	Swap (1)	-	-	1	0.47
Other	-	-	Name (1)	ID number (1)	2	0.93

One student statement for each category given in Table 28 is given below respectively:

BE93: "The variable is like a fight, because either you are right or your opponent is right."

BE1: "The variable is like the horizon line, because they are endless like x and y."

BK14: "The variable is like love, because without them there is no equation, without love there is no life."

BE18: "The variable is like swap, because it means exchange."

CE36: "The variable is like a human name, because it is unique and they stand alone in questions like a name."

According to the metaphor explanations, the metaphors developed for the concept of variable were divided into six conceptual categories in ĤSS, eight in HSS, six in LSS and four in ĹSS. The categories of "Variable Belonging to Live/Living", "Inanimate/Inanimate Variable" and "Relating to the Unknown" are the common categories created in all four secondary schools.

Findings Related to the Second Research Problem

In this section, the findings related to the problem *"Do the metaphors and metaphor drawing ratios developed for the concepts of ordered pair and variable differ according to gender?"* are presented. Differentiation of students' metaphorical perceptions of ordered pair and variable concepts according to gender variable was analyzed.

Table 29. Distribution of Metaphors Related to the Concept of Ordered Pair by Gender

	Student Creating Metaphor		Student Who Cannot Create Metaphor		Total		Chi-Square		
	f	%	f	%	f	%	x^2	df	p
Female	88	43.35	115	56.65	203	100	3.278	1	.070
Male	68	34.52	129	65.48	197	100			
All	156	39.00	244	61,00	400	100			

According to Table 29, valid metaphors were created by 88 (43.35%) of 203 female students and 68 (34.52%) of 197 male students. There is no significant correlation between gender and the rate of metaphor development related to the concept of ordered pair (X^2 =3.278; p=.070>.05).

Table 30. Distribution of Metaphor Drawings Related to the Concept of Ordered Pair by Gender

	Student Using Metaphor Drawing		Student Not Using Metaphor Drawing		Total		Chi-Square		
	f	%	f	%	f	%	x^2	df	p
Female	54	61.36	34	38.64	88	100	0.184	1	.668
Male	44	64.71	24	35.29	68	100			
All	98	62.82	58	37.18	156	100			

According to Table 30, the drawings in the drawing box were created by 61.36% (f=54) of female students and 64.71% (f=44) of male students who created valid metaphors. There is no significant correlation between gender and the rate of using metaphor drawings related to the concept of ordered pair (X^2 =0.184; p=.668>.05).

Table 31. Distribution of Metaphors Related to the Concept of Variable by Gender

	Student Creating Metaphor		Student Who Cannot Create Metaphor		Total		Chi-Square		
	f	%	f	%	f	%	x^2	df	p
Female	127	62.56	76	37.44	203	100	13,605	1	.000
Male	87	44.16	110	55.84	197	100			
All	214	53.50	186	46.50	400	100			

According to Table 31, valid metaphors were created by 127 (62.56%) female students and 87 (44.16%) male students. There is a significant correlation between gender and the rate of metaphor development related to the concept of variable (X^2 =13.605; p=.000<.05).

Table 32. Distribution of Metaphor Drawings Related to the Concept of Variable by Gender

	Student Using Metaphor Drawing		Student Not Using Metaphor Drawing		Total		Chi-Square		
	f	%	f	%	f	%	x^2	df	p
Female	57	44.88	70	55.12	127	100	5,316	1	.021
Male	53	60.92	34	39.08	87	100			

All	110	51.40	104	48.60	214	100

According to Table 32, the drawings in the drawing box were created by 44.88% (f=57) of female students and 60.92% (f=53) of male students who created valid metaphors. There is a significant correlation between gender and the rate of using metaphor drawings related to the concept of variable (X^2 =5.316; p=.021<.05).

Findings Related to the Third Research Problem

In this section, the findings related to the problem *"Do the metaphors developed for the concepts of ordered pair and variable differ according to socioeconomic status?"* are presented. Differentiation of students' metaphorical perceptions of ordered pair and variable concepts according to socioeconomic status was analyzed.

Table 33. Comparison of Metaphor Rates Related to the Concept of Ordered Pair by Socioeconomic Status

	Student Creating Metaphor		Student Who Cannot Create Metaphor		Total		Chi-Square		
	f	%	f	%	f	%	x ²	df	p
High socioeconomic status	113	45.93	133	54.07	246	100	12,917	1	.000
Low socioeconomic status	43	27.92	111	72.08	154	100			
All	156	39.00	244	61,00	400	100			

According to Table 33, metaphors for the concept of ordered pair were developed by 45.93% of the students in schools with high socioeconomic status and 27.92% of the students in schools with low socioeconomic status. There is a significant correlation between the rate of metaphor development related to the concept of ordered pair and socioeconomic status (X^2 = 12.917, p= .000<.05).

Table 34. Comparison of Metaphor Rates Related to the Concept of Variable by Socioeconomic Status

	Student Creating Metaphor		Student Who Cannot Create Metaphor		Total		Chi-Square		
	f	%	f	%	f	%	x ²	df	p
High socioeconomic status	140	56.91	106	43.09	246	100	2,988	1	.084
Low socioeconomic status	74	48.05	80	51.95	154	100			
All	214	53.50	186	46.50	400	100			

According to Table 34, metaphors related to the concept of variable were developed by 56.91% of the students in schools with high socioeconomic status and 48.05% of the students in schools with low socioeconomic status. There is no significant correlation between socioeconomic status and the rate of creating metaphors for the concept of variable (X^2 =2.988, p= .084>.05).

DISCUSSION & CONCLUSION

In this study, students' perceptions of ordered pair and variable concepts were revealed and the change in the rate of metaphors developed for these concepts according to gender and socioeconomic status was analysed. Firstly, data on eighth grade students' metaphorical perceptions of these concepts were collected through MPF. A total of 86 metaphors for the concept of ordered pair were created by 156 (39.00%) students, and the most common metaphors were *friend*, *buddy*, *sibling*, *school desk*, and *twins*. The metaphors developed for the concept of ordered pair were grouped under 17 conceptual categories, taking into account the explanation part starting with "because", and the most common categories were "Sequentiality", "Togetherness", "Duality", "Relationship with Number Two", respectively. The ordered pair was the concept that students had the most difficulty in creating metaphors. With the metaphors of friend, buddy, twins and school desk, the students made associations with situations or objects that are associated with the name of the concept and contain sequential or binary features. It was observed that metaphors were created without taking into account the fact that the ordered pair specifies a point in the

coordinate system and its location features, and without considering that the point will be different when its abscissa and ordinate are changed. However, the fact that 98 (62.82%) students clarified the concept of ordered pair by means of drawing supports this result. This result is supported by the fact that there are studies in the literature that there are difficulties in expressing functions with ordered pair (Hatısaru & Erbaş, 2013; Tall & Bakar, 1991; Yıldırım, 2003). The concept of ordered pair has an important place in high school mathematics teaching. A good knowledge of the properties of the point in the analytic plane enables the understanding of cartesian product, relations and functions, limit, derivative and integral. Otherwise, it is obvious that there will be difficulties in learning subjects involving ordered pair representations (Çelik & Türkelli, 2018; Hatısaru & Çetinkaya, 2011). Ural (2012), in his study in which he determined the ability of students to transfer their function definition knowledge to various function representations, stated that errors were made in examining the graph as a set of ordered pairs. Hatısaru & Erbaş (2013) asked students to write the given dishes as ordered pair. It was determined that most of the students left this question blank. Afterwards, it was observed that most of the students gave wrong answers to the question of which of the relations given to the students with the list method was a function and they randomly formed ordered pairs. Moralı et al. (2004) examined the misconceptions or missing information that may occur in the abstract mathematics course and found that very few of the prospective teachers answered the question of finding the inverse of the conjunction of two relations whose elements are given explicitly as ordered pairs on a finite set correctly.

115 metaphors for the concept of variable were developed by 214 (53.50%) students. The most common metaphors developed by the students were *human*, *emotion*, *chameleon*, *dollar*, *weather forecast*, *life*, *decision* and *foreigner*. The metaphors developed for the concept of variable were grouped under 10 conceptual categories. It was observed that the students developed metaphors mostly in the category of "Variable Belonging to Live/Living". Students established a relationship between human, emotion and chameleon metaphors and things that are not fixed and differentiated. It was observed that students developed metaphors mostly in the category of "Inanimate/Inanimate Variable" in the second place. In this category, a constantly changing situation was emphasised with dollar and weather forecast metaphors. In general, instead of the mathematical meaning of the variable, a relationship was established with the word meaning. The studies in the literature, which show that there are difficulties in algebra learning due to different uses of mathematical symbols and letters (unknown, variable, parameter, constant) and not knowing the properties of the variable, are in parallel with this result (Akkan, 2009; Birgin & Demirören, 2020; Dede et al., 2002; Kar et al., 2011; Kaya, 2017; Küchemann, 1978). According to Arcavi and Schoenfeld (1988), algebra is based on variable properties, operations and relationships between variables. According to Birgin and Demirören (2020), a good understanding of the variables that form the basis of algebra, a good knowledge of their qualities and an understanding of the relationships between variables guarantee future mathematics learning. According to Kieran (1990), if the symbols used instead of variables or unknowns are interpreted as letters, some errors may occur. Usiskin (1988) states that *"Students think of the expression 6e as 6 apples rather than 6 times the number of apples (unknown). Here, the letter is the object or concept that is meant rather than the number of objects."* Erdem (2013) determined that 7th grade students could not create the coefficient relationship between variables. Şimşek and Soylu (2018) stated in their study that seventh-grade students ignored the variable and incorrectly constructed an equation suitable for a given problem. Birgin and Demirören (2020), in a study examining the achievement performance of secondary school students on algebraic expressions, stated that some students had the idea that the values of letter symbols increased according to the order in the alphabet. Katrancı and Yıldız (2022) examined the metaphorical perceptions of prospective secondary school mathematics teachers about the concept of algebra and stated that prospective teachers had a negative attitude towards algebra by developing many metaphors in the difficult and complex category. Çolak and Akıncı (2023) stated that eighth grade students had difficulty in forming mathematical discourse about linear equations.

When the rates of metaphor development according to gender were analysed, 43.35% of female students and 34.52% of male students were able to develop metaphors for the concept of ordered pair; 62.56% of female students and 44.16% of male students were able to develop metaphors for the concept of variable. It was observed that female students were able to develop metaphors for both concepts proportionally more than male students. In addition, a significant difference was found in favour of female students for the concept of variable. These results are in parallel with the studies in the literature. Şengül et al. (2014) examined secondary school students' metaphorical perceptions of the concept of "mathematics teacher" and found that female students produced more metaphors than male students. Doğan and Sönmez (2019) examined the metaphorical perceptions of fourth grade students towards the mathematics course and determined that female students developed more diverse and numerous metaphors than male students. Kebap and Çenberci (2020) examined secondary school students' metaphorical perceptions of the concept of "mathematics course" and "mathematics teacher" according to gender

and stated that female students generally produced more valid metaphors than male students. Çekirdekci (2020) examined the metaphorical perceptions of fourth grade primary school students towards mathematics course and stated that female students developed more metaphors than male students. Similarly, Sulhan et al. (2024) examined eighth grade students' metaphorical perceptions of LGS mathematics questions and found that female students developed more metaphors.When metaphor drawings were analysed according to gender, 61.36% of female students and 64.71% of male students who created metaphors for the concept of ordered pair used drawings. While 44,88% of female students and 60,92% of male students who developed metaphors for the concept of variable used drawings. It was determined that the rate of expressing the metaphors developed by male students using drawing was higher than that of female students. A significant difference was found in favour of male students regarding the concept of variable. In the literature, there are studies examining student metaphor drawings (Ada, 2013; Dönmez, 2017; Soydan, 2021; Sönmez & Yılmaz, 2023; Yücel-Cengiz & Ekici, 2019). Doğan & Sönmez (2019) examined the metaphorical perceptions of fourth grade students about mathematics through visuals and stated that female students used more drawings. Cansız et al. (2024) determined the metaphorical perceptions of seventh-grade students towards the concepts of ratio and proportion and stated that female students used more metaphor drawings related to these concepts. However, as can be seen in other studies examining metaphor drawings by gender (Benek & Akçay, 2018; Özcan & Demirel, 2019), there are differences between the results of this study and the studies in the literature. However, there are also studies in which metaphor drawings were examined but no differentiation was examined according to gender (Bozdoğan & Güven, 2021; Gülen & Dönmez, 2020; Ünalan, 2022).

The rates of metaphor development according to socioeconomic status were analysed for both concepts. Regarding the concept of ordered pair, 45.93% of metaphors were developed in schools with high socioeconomic status and 27.92% in schools with low socioeconomic status. Regarding the concept of variables, 56.91% of metaphors were developed in schools with high socioeconomic status and 48.05% in schools with low socioeconomic status. Students in schools with high socioeconomic status developed more metaphors for both concepts. However, a significant difference was found in favour of the schools with high socioeconomic status in creating metaphors for the concept of ordered pair. In literature, there are no studies in which the metaphor frequencies developed are analysed according to socioeconomic status. However, there are studies comparing student perceptions and conceptual categories according to socioeconomic status (Akbulut et al., 2017; Arık & Yılmaz, 2017). Özdemir (2012) examined the metaphorical school perceptions of high school students in terms of various variables and found that the metaphorical school perceptions of students from low-income families were positive at the highest level and that this perception tended to decrease with increasing income level. Çırak (2014) examined the metaphorical perceptions of secondary school teachers about the concept of ‘student’ and stated that teachers in schools with high socioeconomic environment had a more positive perception of students. These studies show that the social environment in which an individual lives and the economic opportunities he/she has will directly affect the quality of the education he/she receives, and it is expected to affect the way he/she perceives mathematical concepts and the meanings he/she attributes to them.

Some suggestions that will shed light on future studies are presented. It was observed that students had difficulty in developing metaphors for the concepts of ordered pair and variable. During the teaching of these concepts, using concrete examples appropriate to their qualities can provide effective learning. It was observed that students in schools with low socioeconomic status developed fewer metaphors. Mathematics education of students studying in disadvantaged schools should be qualified. This study was conducted with eighth grade students. It is important to examine the metaphorical perceptions of students from different grades and school levels about linear equations.

Implications

Metaphors are one of the most effective tools for revealing student perceptions. Students' perceptions of mathematical concepts are expected to guide their future learning. In this study, students' perceptions of the concepts of ordered pair and variable were examined through metaphors. It was determined that students had difficulty in creating metaphors for these concepts. It is important to present the concepts of ordered pair and variable in a more understandable way in the classroom environment. In addition, it is thought that explaining the concepts by using metaphors containing the properties of mathematical concepts can make learning more permanent. When analyzed by gender, it was determined that female students developed more metaphors than male students. The opposite situation was realized in metaphor drawings. Considering socioeconomic characteristics, it was determined that students with high socioeconomic characteristics were more successful in creating metaphors for the concepts of ordered pair and variable.

Limitations

The research data is limited to the students of four different secondary schools selected according to the maximum diversity sampling method in a province in the Black Sea Region in the 2021-2022 academic year. The research is limited to the metaphors developed by the students in these secondary schools. The research is limited to the question items in the interview forms.

Statements of Publication Ethics

I declare that we obey the principles of publication ethics. Ethical approval (number and date: 148722-25.03.2022) was taken from Tokat Gaziosmanpaşa University.

Conflict of Interest

There is no conflict of interest in this study

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