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Metaphoric Perceptions of High School Students about Functions

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Abstract This research was aimed to indicate how high school students use metaphors to think about math "functions". A total of 405 students were asked to complete the phrase, "Function is like..…. because……" Students were given sheets and asked to write their thoughts while focusing on one metaphor. The data from this research was analyzed through a content analysis method. The metaphors were determined, classified and categorized. A total of 149 valid metaphors were identified and classified under eight different categories. The research results indicated that more than half of the students think that function is a difficult concept, some students found the concepts of polynomial and function similar to each other, and some expressed that they found the subject of function easy and enjoyed solving problems related to functions.

Keywords: *Mathematics, function, metaphoric perception, high school student*

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1. Introduction

The aim of education in our country, and the world, is to train individuals who can keep up with our rapidly changing world. Since it became essential to train individuals in analytical thinking and finding solutions to problems in the rapidly changing world, mathematics education has become especially important.

Function, which is an important subject in mathematics, is one of the distinctive features of classical and modern mathematics [1]. In contemporary mathematics, functions began to be included in the foundation of mathematics programs of countries [2]. In many countries, functions became a substantial subject because of both being incorporated in high school teaching programs starting from the ninth grade and taking place in many subjects before and after. The concept of function is a rather abstract one, which students encounter during high school education because it is related to subjects such as drawing and reading graphs of functions, limit, derivative, integral, etc. It was also explained by the NCTM [3] that function is an important and effective concept in every field from basic mathematics to algebra and geometry. In other words, *function* is a foundational concept for many other concepts.

Leibnitz gave the first definition related to function as having shown development within different mathematicians' definitions and studies in the 17th century. According to him, a tangent is a catenary function. For the first time, Dirichlet defined *function* as matching beyond catenary or analytical expression and "certain sub-sets of the ExF Cartesian product" [1]. From the 1960s on, this definition took hold in mathematics courses in the form of "a match between two non-empty sets taking each element to only one element" [4]. *Function* can also be defined as a correlation "matching every element of a set with only one element of a second set" [5]. These are verbal definitions of function. In math classes, after giving these definitions, *function* is explained via set matching diagram and different representations (set matching diagram, ordered pairs set, equations and graphs) are exemplified [4]. Different representations might increase the comprehensibility and long-term ability of students to retain the concept.

Many studies have been conducted about functions [1,2,4-12]. These studies examined how students of varying levels defined function and that these students had difficulty in understanding the subject of function, were less knowledgeable about the definition of function and could not express the function with multiple representations. As a result, all of these studies explained that the reasons why the participants had inadequate or incorrect knowledge about functions were: poor definitions made in lessons and insufficient importance attached to creating definitions.

In planning teaching, the principle of leading students 'from known to unknown' and 'from concrete to abstract' should be adopted. It is difficult for individuals to understand abstract concepts compared to concrete concepts. For this reason, it is important to associate abstract concepts with concrete ones. A method used for this purpose is metaphorical thinking. In metaphorical thinking, individuals explain unknown or difficult-to-understand concepts with a known concept, object or action. In other words, a metaphor explains a difficult-to-understand concept

by associating it with another known, understandable object, concept or action. Therefore, metaphors are used as a tool for inquiring about a concept and also gathering information in order to help students understand abstract subjects better [13]. Moreover, students, teachers, and student-teachers' metaphors mostly explained in relation to the concepts of *mathematics* and *mathematics teachers* were explained in different studies concerning mathematics education [14,21]. In other words, these studies put forward a general perception about mathematics course and teachers. However, there are not many studies on more specific subjects in mathematics education. For this reason, unlike other studies, metaphors created by the students in a mathematics course dealing with the concept of *function* (to which importance is attached starting from the first year of secondary education), were examined in this study. Answers were sought to the following research problems:

1. What metaphors do high school students have in relation to the concept of function?
2. Under which categories can these metaphors be classified according to their shared characteristics?

Although the concept of function is the building block of many branches of mathematics, it is explained in many studies that it is difficult for students to understand. This study attempts to make a contribution to the field by demonstrating how high school students perceive the concept of function by using metaphors.

2. Methodology

2.1. Research Method

In this qualitative study, the *phenomenological* design was used as a research design. The *phenomenological* design helps to get individuals' opinions about a subject or an event and hence get to know about the subject or the phenomenon better ([22]:75-77).

2.2. Participants

This study was carried out with a total of 405 tenth, eleventh and twelfth grade students from four different high schools (Science High School, Anatolia High School, Social Sciences and Religious Vocational High School) in a large city in the spring semester of the 2014-2015 academic year. Careful attention was paid in choosing students to voluntarily participate in the study. However, since the subject of functions is taught for the first time in the spring semester of the ninth grade, ninth grade students were not included in the study. The pieces of information about the participant high school students are given below.

Table 1. Information about Participants

	10th grade		11th grade		12th grade		Total	
	f	%	f	%	f	%	f	%
Female	77	19.0	67	16.5	70	17.3	214	52.8
Male	79	19.5	68	16.8	44	10.9	191	47.2
Total	156	38.5	135	33.3	114	28.2	405	100.0

2.3. Data Collection

At this stage, first of all, the tenth, eleventh and twelfth-grade students were given information about the study and metaphor was defined briefly. Then, pieces of paper with a statement "Function is like … because …" on them were handed out to them and they were asked to complete this statement. When completing this statement, they were asked to concentrate on a single metaphor for the first blank and then explain the reason why they had chosen that metaphor in the second blank. It took about 10 minutes to complete this statement.

2.4. Data Analysis

In the analysis of the obtained data, the content analysis method was used. In this method, firstly pieces of obtained data are made sense of, and then they are put into certain categories and finally examined. The researchers read all the pieces of paper and listed the metaphors via collaborative work. A total of 48 pieces of paper were excluded because they had no metaphors or reasons on them. The metaphors which were synonyms of, or similar to one another, were classified and 149 metaphors were obtained. Then, each created metaphor was categorized by the researchers according to reasons for selection and shared characteristics via association with certain themes. To understand the reasons for the metaphors belonging to these categories, their statements were included as well. Finally, these determined categories were compared, discussed and, as a result, eight different categories were created. The Microsoft Excel program was used in the determination of these metaphors and the creation of these categories.

2.5. Findings and Interpretations

In this section, the metaphors obtained within the scope of the study with the aim of examining the participant high school students' metaphors about the concept of function, and then the findings were reached as a result of the statistical analyses and the interpretations of these findings. A total of 149 metaphors obtained within the scope of this study were divided into a total of 8 different categories. The categories belonging to the metaphors were *difficult/impossible, basis for other subjects/necessary, related to the definition, long/complicated, frightening/boring, requiring skills, amusing/popular* and *other*. The statistical data belonging to these obtained categories is given in Table 2.

Table 2. Distribution of Metaphors Created by Students about Function into Categories

Rank	Category	f	%
1	Difficult/Impossible	94	26.33
2	Frightening/Boring	56	15.68
3	Related to the Definition	53	14.85
4	Necessary/Basis for other subjects	49	13.73
5	Amusing/Popular	44	12.33
6	Long/Complicated	31	8.68
7	Other	20	5.60
8	Requiring skills	10	2.80
	Total	357	100.00

The metaphors included under the category heading of *Difficult/Impossible* are the ones expressing difficulties in relation to the subject of functions. That the participating students mostly used the metaphors included in this category in their statements (26.33%) indicates that the subject of functions was described as a difficult subject. However, in their explanations, some students emphasized that it was nearly impossible to learn the subject of functions. The second mostly repeated metaphor (15.68%) was the metaphor of '*frightening/boring*,' which was again a negative one. Again, the category of '*long/complicated*,' in which some students' (8.68%) statements were included, was a negative category. When these three categories were taken together, it was understood that more than half of the students (50.69%) created negative metaphors in relation to the concept of function. In the following tables, the metaphors included within the scope of each created category were given.

The metaphors and statistics belonging to the category of '*difficult/impossible*' are given in Table 3. It was observed that the participant students used the metaphor of *life* in this category most frequently. Moreover, the second most frequently used metaphor was the metaphor of *people* which showed similarity with the metaphor of *life*.

The metaphors listed under the category of *frightening/boring*, the second most used category related to the function are listed below. In this category, some students (5.60%) repeated the metaphor of *unnecessary subject*, which was the most frequently used metaphor. While a few students emphasized the frightening aspect of the subject of function, they expressed this concept with the metaphors of *nightmare*, *the very devil*, and *torture*. Moreover, the metaphors included under this category heading had another prominent shared characteristic. They explained their thoughts through some metaphors that function, and related subjects have an important place in the distribution of questions in the university entrance exams. For this reason, they expressed their thought in their explanations that although they found this subject boring or frightening, they had to learn it. The frequency and percentage distributions listed under the category of *related to the definition* are given in Table 5.

Table 3. Metaphors in relation to the Category of '*Difficult/Impossible*'

Rank	Metaphor	f	%	Rank	Metaphor	f	%
1	Life	38	10.65	8	Boomerang	1	0.28
2	People	23	6.44	9	Blind alley	1	0.28
3	Love	8	2.24	10	Lighthouse	1	0.28
4	Woman	8	2.24	11	Needle in the haystack	1	0.28
5	A difficult subject	8	2.24	12	Going up the hill	1	0.28
6	Sports car	2	0.56	13	Swimming of a giraffe	1	0.28
7	Swimming in a swamp	1	0.28				
			Total			94	26.33

Table 4. Metaphors in relation to the Category of '*Frightening/ Boring*'

Rank	Metaphor	f	%	Rank	Metaphor	f	%
1	Unnecessary subject	20	5.60	16	Stomach ache	1	0.28
2	Nightmare	3	0.84	17	A bad meal	1	0.28
3	The very devil	2	0.56	18	Unused thing	1	0.28
4	Debt	2	0.56	19	Undergraduate Placement Exam	1	0.28
5	Torture	2	0.56	20	12-year compulsory education	1	0.28
6	Lots of operations	2	0.56	21	Death	1	0.28
7	A boring film at the cinema	2	0.56	22	Watching an exploding volcano	1	0.28
8	Love movie	1	0.28	23	Monday syndrome	1	0.28
9	Arabesque	1	0.28	24	Leek	1	0.28
10	Stumping	1	0.28	25	Distresses	1	0.28
11	Diet	1	0.28	26	Mosquito	1	0.28
12	An apple with a worm in it	1	0.28	27	Joke	1	0.28
13	Illness	1	0.28	28	Stone	1	0.28
14	A stubborn enemy	1	0.28	29	Mother of all evils	1	0.28
15	A black hole	1	0.28	30	Virus	1	0.28
				Total		56	15.68

Table 5. Metaphors in relation to the Category of '*Related to the Definition*'

Rank	Metaphor	f	%	Rank	Metaphor	f	%
1	Machine	25	7.01	10	Variable	1	0.28
2	Mother–child relation	3	0.84	11	Invention	1	0.28
3	Factory	3	0.84	12	Broken mirror	1	0.28
4	Plate	3	0.84	13	Hairdresser	1	0.28
5	Workshop	2	0.56	14	User's manual	1	0.28
6	Empathy	2	0.56	15	mRNA (Messenger RNA)	1	0.28
7	Matching	2	0.56	16	History	1	0.28
8	Selection	2	0.56	17	Field	1	0.28
9	Remote control	2	0.56	18	Pan	1	0.28
					Total	53	14.85

The common characteristic of the metaphors in this category is that they include much assimilation related to the definition of *function* given in lessons. The mostly-repeated metaphor was the *machine*. The participants emphasized machines' feature of processing a given raw material. Moreover, the metaphors of *factory* and *workshop* have parallel meanings. With these metaphors, it was emphasized that they match each element of the domain set of a function with an element from a codomain set.

After that, the metaphor statistics belonging to the category of *basis for other subjects/necessary* included within the scope of this study are given in Table 6. In this category, the students expressed especially with using the metaphors of *base of the building (2.53%), polynomial (1.68%)* and *tree roots (0.84%)*, etc. that the concept of function was the building stone of many subjects. In fact, these metaphors, especially the metaphor of *polynomial* used by a total of 6 students, are attention-grabbing. The students found the concepts of polynomial and function similar to each other. In fact, a polynomial is a function defined via special terms. The function is the basis of many subjects like this.

The statistics related to the metaphors pointing to the fact that function is *amusing/popular* are given in Table 7. Under this category, the metaphor of *game* was mostly repeated (3.64%). With some metaphors the students wrote in this part, some expressed that they found the subject of function easy and enjoyed solving problems related to this subject. In this context, the students writing the metaphors included in this category wrote such metaphors as *an easy subject (2.24%), puzzle (1.40%)* and *riddle (0.56%)* in addition to the metaphor of *game*.

The frequency and percentage values are pointing to the fact that function is a *long/complicated* subject are given in Table 8. When the metaphors included in Table 8 and with which the students described the subject of function as *long/complicated* were examined, it was observed that a total of 8 students regarded function as a *long road* whose end cannot be seen. However, a total of 3 students described *function* with a parallel statement as a very complicated subject having many subjects and encountered everywhere just like *mathematics*. Moreover, the metaphors which the students created in relation to the fact that function is a *skill-requiring* concept are given in Table 9.

Table 6. Metaphors in relation to the Category of 'Basis for other subjects/*Necessary*'

Rank	Metaphor	f	%	Rank	Metaphor	f	%
1	Base of the building	9	2.53	14	Buttoning	1	0.28
2	Polynomial	6	1.68	15	Core of the world	1	0.28
3	Tree roots	3	0.84	16	Rising main of the house	1	0.28
4	Water	3	0.84	17	Lettuce	1	0.28
5	Friend	2	0.56	18	Entrance door of mathematics	1	0.28
6	Father	2	0.56	19	Half of mathematics	1	0.28
7	Dreams	2	0.56	20	Matryoshka	1	0.28
8	Engine	2	0.56	21	Parsley	1	0.28
9	Kitchen	2	0.56	22	Advice	1	0.28
10	Jigsaw puzzle	2	0.56	23	Vegetable	1	0.28
11	Breast milk	1	0.28	24	Love	1	0.28
12	Brain	1	0.28	25	Brick	1	0.28
13	Domino stones	1	0.28	26	Tram driver	1	0.28
					Total	49	13.73

Table 7. Metaphors in relation to the Category of '*Amusing/Popular*'

Rank	Metaphor	f	%	Rank	Metaphor	f	%
1	Game	13	3.65	10	Ice tea	1	0.28
2	An easy subject	8	2.24	11	Eating kunafah after iskender-kebab	1	0.28
3	Puzzle	5	1.40	12	Cooking cookies	1	0.28
4	Riddle	2	0.56	13	Taste of mathematics	1	0.28
5	A nice meal	2	0.56	14	Pony	1	0.28
6	Theatre	2	0.56	15	Nicotine	1	0.28
7	Ball	2	0.56	16	Sugar	1	0.28
8	Sunflower seed	1	0.28	17	Poem	1	0.28
9	Fish	1	0.28				
					Total	44	12.33

Table 8. Metaphors in relation to the Category of '*Long/Complicated*'

Rank	Metaphor	f	%	Rank	Metaphor	f	%
1	Road	8	2.24	11	Chaos	1	0.28
2	Mathematics	3	0.84	12	Mixed fruit-flavored gum	1	0.28
3	Dead well	2	0.56	13	Rubber	1	0.28
4	Earphone	2	0.56	14	The Painting of Mona Lisa	1	0.28
5	Labyrinth	2	0.56	15	Events	1	0.28
6	Stock market	1	0.28	16	In a pretty scrape	1	0.28
7	Deep pool	1	0.28	17	A policeman in a detective novel	1	0.28
8	Universe	1	0.28	18	Rubik's cube	1	0.28
9	Italian salad	1	0.28	19	Eternity	1	0.28
10	Roll of papers	1	0.28				
					Total	31	8.68

Table 9. Metaphors in relation to the Category of '*Requiring Skills*'

Rank	Metaphor	f	%	Rank	Metaphor	f	%
1	Solving paragraph questions	3	0.84	4	Computer programming	1	0.28
2	Football match	2	0.56	5	Reward for efforts	1	0.28
3	Gambling	2	0.56	6	Gordian knot	1	0.28
					Total	10	2.80

Table 10. Metaphors which the Students Created in relation to the Category of '*Other*'

Rank	Metaphor	f	%	Rank	Metaphor	f	%
1	Dance of lines	1	0.28	11	Shoemaker	1	0.28
2	Dinosaur	1	0.28	12	Probability	1	0.28
3	Nature	1	0.28	13	Bus	1	0.28
4	Electric leakage	1	0.28	14	Poker	1	0.28
5	Donkey	1	0.28	15	An ordinary subject	1	0.28
6	Offspring	1	0.28	16	Sparkling water	1	0.28
7	Redness of the Sun	1	0.28	17	Message	1	0.28
8	Tightrope walker	1	0.28	18	Iron	1	0.28
9	Complex numbers	1	0.28	19	Unfaithful person	1	0.28
10	Book	1	0.28	20	Rain	1	0.28
					Total	20	5.60

The statements which the students wrote in this part, though few, were the ones emphasizing the importance of knowing the concept of function and its characteristics well in solving problems related to the subject.

Finally, the other metaphors which the students used in relation to function and the statistics about these metaphors are given in Table 10. A total of 20 metaphors belonging to this category were reached. Since the metaphors each reveal a different aspect of the function, they could not be placed in the other categories.

3. Discussion and Conclusion

The function is included in the definitions of many mathematical subjects and concepts. As was stated before, first of all, the function should be understood well as the subject from which most questions come in undergraduate placement examinations. For this reason, in this study, the metaphors that the high school students created about *function* were examined, and a total of 149 metaphors were obtained.

These metaphors were divided into 8 different categories according to their shared characteristics. According to this, an important part of the students (about one- fourth of them) described the concept of function as *difficult/impossible*. Besides this, an important part of the students (15.67%) created metaphors that they find the concept of function as *frightening/boring*. Again, a few of them stated finding this concept as *long/complicated* with the metaphors they wrote. The students stated that the subject was too long, became complicated as it grew longer and included many definitions and characteristics. When these three categories (frightening/boring, difficult/impossible and long/complicated) were taken together, it was understood that more than half of the students created negative metaphors about the concept of function. This result is similar with the results of the studies carried out by Durmus [8], Dikici & Işleyen [7], Kutluca & Baki [9], Oflaz [17] and Tatar, Okur & Tuna [10]. They indicate that the concept of function is a concept perceived as difficult. When the reasons were given by the students for these metaphors, it was understood that they regarded function as a useless subject in their daily lives. When students cannot understand and use a subject outside exams, they describe that subject as difficult and boring [23]. For this reason, to make the seemingly abstract concept of function more understandable, it would be appropriate to give concrete examples associated with daily life in math lessons. However, it is noteworthy that some of the students are aware of the necessity of the concept of function. This indicates that although the students found the concept of function difficult, they were aware of its being necessary.

It was observed that while more than half of the participants created negative metaphors about the concept of function, a few of them (12%) generated metaphors indicating that they loved the function. The analyses showed that these students creating positive metaphors were the ones having learned the concept of function completely and enjoyed solving problems related to the subject by knowing the characteristics of function. Moreover, it is also worth drawing attention to the fact that a significant part of the students (about 15%) created concrete metaphors in relation to the definition of *function*. In this case, using the function machine examples might have caused the students to understand the concept of function in the math lessons better. In this scope, the mostly-repeated metaphor was the metaphor of *machine* supports this. In addition, such metaphors as *factory* and *workshop* are the ones emphasizing the matching of each element of the defining set of function with an element from the value set. This indicates that these students comprehended the concept of function correctly.

Because it is the basis of different subjects such as limit, derivative and integral, high school students encounter functions at almost every stage of their educational lives. In this study, the students who ended up providing negative statements about the subject of function often mentioned their fears that being failure would continue in the following subjects of mathematics. For this reason, it is essential that high school students should learn the concept of function effectively and in an engaging way. The concept should be associated more frequently with everyday life and concretized in order to save the

understanding of function from being *difficult/impossible* and *frightening/boring*. If it is more emphasized in lesson plans, definitions and characteristics related to the concept can be internalized by students.

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