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THE ROLE OF GESTURES IN MATHEMATICAL DISCOURSE OF HARD-HEARING STUDENTS: PRISM EXAMPLE

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Abstract: This paper examines how hearing impaired students defined prism and used gestures in the process of this defining. It was utilized fenomenology of qualitative research methods. Opinions of two hard-hearing students' were consulted. It was used the grounded theory tecniques to analyze the data. Results indicated that the students used iconic, metaphoric and deictic gestures and sign language engaging in mathematics, explained prism as an object which had base, surface and height. It has been found that students have either missing or incorrect information about prisms. Because of the students used the hand movements, it can be suggested that teachers should use hand, arm and body movements in the process of embodying concepts in classroom practices in the present study.

Key words: geomerty; prism; hard-hearing students

1. Introduction

Geometry, in mathematics, facilitates the understanding of shapes and underlying features and life (Goos & Spencer, 2003) by providing individuals reasoning and problem solving ability in perceiving spatial and physical situations (Battista, 2007). Therefore, geometry is not only a learning space, but also an important tool in recognizing and understanding the physical environment lived in (NCTM, 2000). Most subjects in geometry contain abstract concepts, especially geometrical objects require more complex thinking by using the imagination of students (Yıldız, 2009). Turgut (2007) stated that spatial capability is necessary to move or reconstruct in mind objects and components in three-dimensional space. NCTM (2000) also explains about the necessity of spatial ability to understand, explain and evaluate geometric world, and states that children's reasoning and visualization skills related to spatial relationships are important components of geometry. So, the existence of spatial ability to understand, describe, and deal with geometric objects in their minds is indisputable. The ability to transform two- and three-dimensional geometric forms as a whole in the mind and to recognize them in various positions (Olkun & Altun, 2003) actualizes thanks to spatial skill. Therefore, it is possible to say that students use their spatial ability in defining three-dimensional objects.

There are individuals in society who need special education with developmental characteristics and significant differences from their peers, one of whom is hearing impaired. These children also need to learn mathematics in order to be able to live active, successful and independent in society. Most studies have shown that hearing impaired individuals fails in mathematics, but some studies proved that hearing impaired students have an advantage in visual ability (Hall & Bavelier, 2010; Rettenbach, Diller, & Sireteanu, 1999). Marschark and Hauser (2012) also stated that visual spatial skills of hearing impaired students are generally better than hearing students. Therefore, it was wondered the knowledge that the hearing-impaired students have about geometric objects, including spatial skills.

In recent years, researchers has needed to consider the role of gestures which are movements of the hands and body when engaged in a mathematical activity, such as speaking, thinking, learning or solving problems not only in communication but also in shaping and construction of mathematical meanings and concepts (Arzarello, Paola, Robutti, & Sabena, 2009). Many recent studies have

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documented that the gestures have played a important role in cognition and they have emphasized that gesture are not mere vehicles of thought but active and genuine constituents of thought (McNeill, 2005). Also, McNeill (1992) argues that gestures reflect mental images. The current paper has focused how the gestures are used to help construct and communicate mathematical understandings by the hard of hearing students and wanted to detect thoughts about prism which is geometric object and includes spatial ability in the people's mind through gestures. Most gesture theorists state that it is interesting to examine how such abstract concepts are made present through the physicality of gestures (Arzarello, Robutti & Thomas, 2015). In literature, it was investigated the role of gestures used hearing students in some subjects; learning counting (Alibali & DiRusso, 1999), classroom communication (Goldin-Meadow, Kim & Singer, 1999), drawing graphic (Arzarello & Robutti, 2003), slope (Yoon, Thomas & Dreyfus, 2011), the formula of derivative (Arzarello, Paola, Robutti, & Sabena, 2009) and fractions (Edwards, 2009). In addition, the role of gestures in hearing students has been investigated in arithmetic operations (Goldin-Meadow, Shield, Lenzen, Herzig, & Padden, 2012). Considering the studies in the field, it was seen that there was no study examining the role of gestures in hearing impaired students about prism. It is asked to investigate how gestures were used by the hearing impaired students in the explanation process of the prism and its features. In the light of the our aims, the problem sentence of the current paper is detected as

- How do hard-hearing students' physical gestures become endowed with mathematical meaning?

1.1. Gestures and Sign Language

Gesture is defined as spontaneous "movements of the arms and hands... closely synchronized with the flow of speech" (McNeill, 1992). Sign languages are visual-spatial languages that have their own grammatical and linguistic structure. Sign language comprises of space, handshape and movement and plays an important linguistic role in constructing visual-spatial expressions (Tomaszewski, 2001). It can be seen that both the gesture and the sign language are produced by hand method in the same way. However, the sign language is a language with similar grammatical properties just like speech (Liddell, 1984), while the gesture is body movements that accompany this language. Gestures can be accompanied by either a sign language or a speech in the hearing impaired a natural language sign language (Gürefe, 2015). So, deaf people have been found to gesture when they sign (Emmorey, 1999; Sandler, 2009). In fact, gestures are seen as accompaniments to talking, while sign language are not seen in individuals who hear.

People utilize gestures to point objects, define concepts (McNeill, 1992), and communicate with symbols and signs (Kendon, 1987). But, in recently, it has been determined that gestures are not only a simple hand gesture but also play an important role in cognition. Recent work in cognitive science and mathematics education has begun to demonstrate that mathematics has both roots and expression in bodily knowing (Edwards, 2009; Radford, 2009). Gestures are shown as a means of understanding students' ways of reasoning in mathematics education (Arzarello, Robutti & Thomas, 2015). That is, gestures produced by people doing mathematics provide a rich source of data information of mathematical concepts and relationships among them in the people's mind (Arzarello, Robutti & Thomas, 2015). Also, Radford (2009) argued that thought does not occur solely in the head but in and through language, body and tools and gestures serve as "windows" on inner thoughts or as conveyors of ideas. It is seen that gestures are important components in the students' processes of knowledge objectification.

McNeill (1992) has further classified gestures in terms of what they refer to. We were interested in iconic, metaphoric and deictic gestures in current paper. Iconic gestures represent concrete images or actions, and their physical forms resemble the visual image. For example in Form 1-Table 1, the student 1 (S1) used iconic gesture which was composed to help defining the shape of a prism. The shape with flat palm in air of the student visually looked alike rectangle or square prism. Metaphoric gestures represent an idea or concept that does not have a physical form. In Form 10-Table 1 used a metaphoric gesture used by the student 2 (S2) while describing the abstract mathematical idea of "infinite" concept. S2 said that "infinite" concept means that goes continuous and never ends. At that time, flat palm which is perpendicular on the ground was moved forwards continuous. Deictic gestures

serve to point objects and events in the concrete world. In Form 35-Table 4, S2 used deictic gesture to point right hand thumb and index finger which represented "perpendicular" concept by left hand index finger. At that time, this gesture set falls into iconic gesture. Right hand fingers in this gesture set were used to show "perpendicular" concept. Because of this, it is iconic gesture. Left hand finger was used to point right hand fingers. Therefore, it is deictic gesture. Parrill and Sweetser (2004) and McNeill (2005) point out that gestures typically load onto more than one dimension. Finally, gestures can be said that serve as a tool to show thoughts.

2. Method

2.1. Research Model

A qualitative research method was used in the study. The focus of this study is gestures that consist of hand movements experienced by students. While hearing impairments students frequently use hand gestures in communication, it was wanted to reveal how the students used gestures in the explaining process of concepts. Because of this, the present study was considered as phenomenology study.

2.2. Participants

Participants in the present study were two hearing-impaired students (S1, S2) selected according to the objective (objective) sample from non-random sampling methods. S1 studied at the 10th grade department of clothing, S2 studied at the 11th grade department of photography. All of them were female. These students were hard-hearing and they lost hearing ability because of a febrile illness that they have in 2-3 years of age. Hearing impairment can be classified as deaf and hard-hearing individual. Deaf individuals are those who are prevented from successfully acquiring knowledge of the language with or without a hearing aid by using their hearing power and hard-hearing individuals are those who have adequate hearing survival and are able to successfully use their hearing aids to gain knowledge of language in the hearing strength direction (Brill, McNeil & Newman, 1986). Participants in the present study also speak through the device in their ear and know sign language very well. Both students took mathematics and geometry courses in grade 9, as well as S2 took perspective courses in 10th grade. The students have learned geometric objects in the course of geometry and perspective courses.

2.3. Data Collection Process and Measurements

Semi-structured interviews were conducted with the students in the current study. During the interview, students were given a form consisting of four open ended questions. In the final form, following questions existed;

- *How do you define prism?*
- *Which features does a shape have to be prism?*
- *How do you explain prism one person who don't know prism?*
- *Can you give me an example for prism?*

In the draft form, there were questions about the students' conceptual knowledge related to prism and operational knowledge related to subject such as surface area and volume. Two mathematics teachers who worked in a hearing impairment school and a lecturer in university were consulted in the process of determining whether the questions were appropriate for the student level. The mathematics teachers of the hearing impaired students specified that these students have conceptual knowledge about prism, but, they did not have much knowledge about subjects such as space area and volüme and it would be more appropriate to remove the operational questions. After the necessary arrangements have been made in terms of language, meaning, suitability to the students' level on the questions, the final form has been created and given to the students in written form. During the research, the students read the questions. When the students didn't understand questions, the researcher explained the questions both

in the sign language and in a loud voice. Interviews were recorded with two video cameras. One of the video cameras was placed in the research environment to record hand movements of the students and the other video camera to display the signs made by the students on paper.

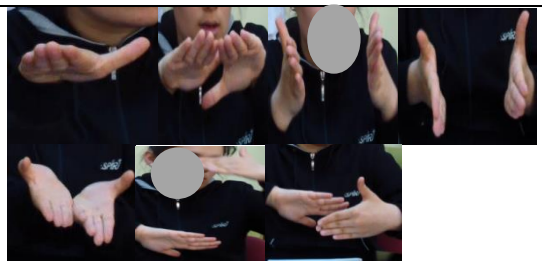
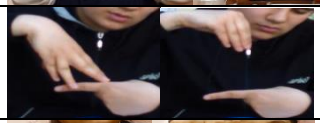
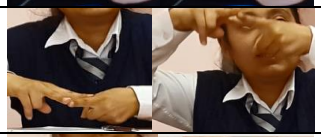
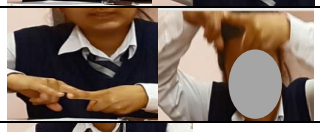
2.4. Data analysis

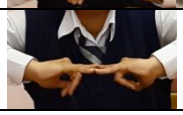
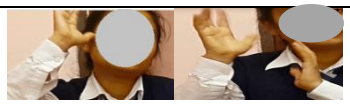
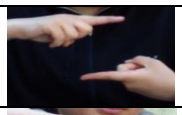
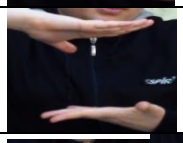
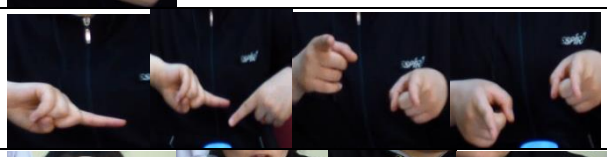
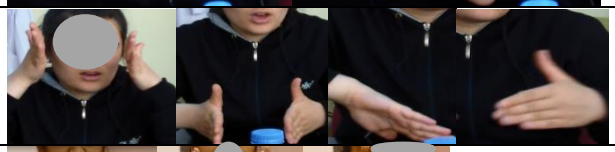
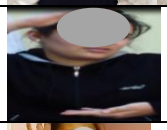
In the current study, it was investigated how gestures were involved in explaining the prism, and therefore the gestures were particularly concentrated. In the analysis of the collected data, open coding, axial coding and selective coding techniques of the grounded theory were used. The gestures were categorized together with accompanying speech. After the categories were determined for each concept, the categories were associated with the subcategories. The researcher consulted opinion of a expert in mathematics education to provide reliability of the coding in research. The researcher was informed the expert about the research topic and the data coding technique and then gave the data to the expert for coding. The consistency of the coding made by the researcher and the expert was calculated as %90. As a result of discussions on non-conforming codes, consensus has been reached

3. Findings

Students were asked to specify prism and features, to give examples for prism, to explain someone who does not know prism. Students have identified the prism as a shape which has base, surface and height, and have described them using various gestures. The gestures used by the pupils regarding the prism concept and its features are given in Table 1.

Table 1. *Geometric concepts and their gestures*

Geometric concepts		Gestures	Form and students
Prism			Form 1 (S1)- Iconic gesture
			Form 2 (S2)- Iconic gesture
			Form 3 (S2)- Iconic gesture
Types	Triangular prism (S1, S2)		Form 4 (S1)- Iconic gesture
			Form 5 (S2)- Iconic gesture
	Square prism (S2)		Form 6 (S2)- Iconic gesture
	Rectangle prism (S2)		Form 7 (S2)- Iconic gesture

	Pentagon prism (S2)		Form 8 (S2)- Iconic gesture
	Hexagon prism (S2)		Form 9 (S2)- Iconic gesture
	Heptagon prism (S2)		
	Octagonal prism (S2)		
Numbers	Infinite (goes continues) (S2)		Form 10 (S2)- Metaphoric gesture
Elements	Base		Form 11 (S1)- Iconic gesture
			Form 12 (S1)- Iconic gesture
	Surface		Form 13 (S1)- Iconic gesture
			Form 14 (S1)- Iconic gesture
			Form 15 (S2)- Iconic gesture
	Height		Form 16 (S1)- Iconic gesture
			Form 17 (S2)- Iconic gesture
Physical property	Inside, outside are full (S1, S2)		

While the prism is being defined, three different gestures have been made for prism, six for prism types, two for base, three for surface and two for height. S1 defined the prism as a shape with three dimensions which are "base, surface and height", S2 made a gesture in Form 4 by telling prism instead of defining the prism. When it was asked to describe the prism to a person who does not know the prism, S2 stated that bottom-upper bases and surface created prism and S2 was moved her hands which were made triangular in the sign language with his fingers along the vertical line, both from top to bottom and from top to bottom. The student has shown that she thought all of the prism as a triangular prism. In the S1's prism gesture, the flat palms of the right and left hand represented the surfaces of the prism. In this gesture, the right and left hands together represented the bottom and upper bases and flat palms of the hands represented four lateral surfaces. This gesture made for the prism was an iconic gesture. The student who performed this gesture used the "full", "no space" concepts for features of the prism, and "quadratic region" concept for surfaces. While S1 was doing gesture in Form 1, "quadratic region" speech accompanied with this gesture. She said that the surfaces

which she represented with flat palm were a quadratic region. Each hand represented a quadratic region, and the six-surfaced shape formed entirely by the hands represented the prism. This gesture set of S1 referred to both the quadratic area, which was the surface of the prism, and the prism formed by the six surfaces. This gesture contained two different iconic gestures. This gesture has shown that the mental image about prism of S1 was a box-like model whose surfaces were square. She didn't realised that she formed a cube. In fact, she generated a special shape of the prism and she called it prism. That is, she thought the prism as the cube shape. The student mentioned the triangular prism outside this, but she used the gesture in Form 4 for this prism. In the gesture, the left hand fingers were turned on while the others were closed, and the right hand fingers were touched on the left hand and lifted upwards and joined at a point above. In this movement, S1 has tried to represent the left hand finger as the base, the right hand fingers as the line segments which composed lateral surface, and the point where the fingers joined as the top point. However, this gesture explained a cone. S1's prism gestures showed that the prism model in the student's mind was a box and a cone. S2 has made seven different gestures to objectify the prism. Two of them represented the prism concept, and five represented the prism types. In the gesture of Form 2, she held that the right and left hand were open, parallel to each other and flat palms facing each other. In this gesture, S2 represented the upper base with right hand and bottom base with the left hand. In this movement, it was seen that the prism was represented as a shape consisting only of the upper and bottom base. In Form 3, S2's both hands were kept as open, parallel to each other and perpendicular on the floor. Then, she was moved her hands from top to bottom, and she represented it as a prism with lateral surfaces and height. In Form 5, the same student made a triangle in sign language with fingers of her right and left hands and this triangle was moved from top to bottom and from top to bottom.

S2's triangle sign referred to sign language, but, the sign made for the triangle prism concept showed an iconic gesture. In this gesture, the student didn't make not only a triangle in sign language, but also she brought in a dimension when she was moving triangle from top to bottom in the vertical direction. So, she carried it to space. Firstly, S2 made this gesture for prism, but later stated that it represented triangle prism. The fact that S2 was particularly common in all the gestures in which it was made for the prism types was that the geometric shapes in the two dimensions were added to one another with the addition of height, and the shape was especially the same. However, not only a box-shaped prism model was created, but triangle, square, rectangle, pentagon and hexagon prism shapes, in which the bases were different polygons, were also formed with hands and fingers. She also mentioned that there were heptagon and octagonal prisms without any gesture, and stated that there were an infinite number of prisms.

Students stated that the prism had a base, surface, and height expressed. S1 used the fingers on Form 11 and flat palms on Form 12. In Form 11, the student held the index fingers of the right and left hand as if they were parallel to each other in the air, emphasizing that the prism had two bases and that these bases were the same and parallel to each other. In Form 12, the same movement was performed with both hands. In relation to the surface, S1 made two different gestures, S2 made one gesture. Both of the S1's gestures were performed in the air, one of them was used fingers of the hands (Form 13) and the other was used flat palms of the hands (Form 14). In Form 13, when the right and left hand index fingers were parallel to each other and floor, they were moved from top to bottom and lateral surfaces were scanned by the fingers. Fistly, the front and rear surfaces were shown, then the lateral surfaces were shown. In Form 14, the same movement was made with both hands. When the hands were parallel to each other and perpendicular to the floor, they were moved from the top to the bottom, and then to the front and back. S2 has used gesture in Form 15 for the surface. This gesture was similar to the gesture in Form 14. However, in Form 14, the surfaces on the imaginary lateral were shown by being scanned by hand, while the flat palms of the hands represented lateral surfaces in Form 15. Signs in Form 14 and Form 15 were iconic gestures. S1 and S2's gestures related to surface concept showed that these students thought of only lateral side for the surface and not the upper and bottom bases.

S1 and S2 have been a gesture for the height concept. Both gestures referred to the same visual. In Form 16, the distance between the hands represented the height concept when the hands were held parallel to each other and to be distance between them. In Form 17, the distance between the hands

was indicated as the height while the hands werere kept in the shape of "o" and parallel to each other. It can be said that one of these gestures (Form 16) intended the distance between the bases of the geometric objects, while the other (Form 17) expressed a straight line. In fact, although both gestures expressed the same visual shape, the meaning of the gestures' construction and their shape differ from each other. Therefore, it can be said that the gestures of the students gave us an idea of the information about their minds. In a sense, these gestures can be seen as a simple pictorial representation of what students think about prism.

3.1. Findings about Base of Prism

The students mentioned about geometric shapes in which the bases could be, the edge numbers of the geometric shapes, the physical appearance, how to name them (Table 2) while they talking about base of prism.

S1 said that base could not be round and had to be a polygon. Also, S2 did not say verbally that the base had to be polygon, but the signs and shapes what they said about base were always polygon, and could not even be round. As polygon, students also taught that base were triangle, square, rectangle, pentagon, hexagon and octagon.

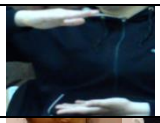
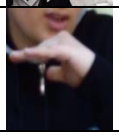
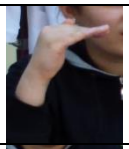
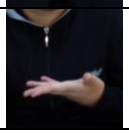
S1 said that bases had edges and the number of these edges should be at least four sides. However, S1 did not mention that the polygon may be triangle. S2 stated that the base could have all the edges from three to nine, and could not have one edge and two edges. Moreover, it was supported by gesture that the base could not have one edge. S2 held the index fingers of the left and right hands at a distance from each other and parallel to the floor (Form 18). This movement in the air showed an iconic and metaphoric gesture. It was a metaphoric gesture because fingers were used to guide the upper and bottom bases and an iconic gesture because fingers visualized one-edged base.

While students were talking about base of prism, S2 mentioned that bases of prism must be the same. Students who commented on the physical appearance of the base stated that base should be smooth, closed and quadratic region but not rotundate. Both students used gestures for the smooth concept. S1 held that the flat palms were the parallel to each other and the floor (Form 19). The smoothness of the prism was visualized by this gesture. It was understood that this gesture represented that the prism should be straight, not skew. S2 also made "o" shape with the thumb and index fingers of the right and left hand for smooth, at first, fingers were united and then removed from each other (Form 20). This movement in the air was a gesture made for the concept of "flat" which means not to be skew. Form 20 was a metaphoric gesture because the concept of smoothness, which is an abstract concept, was embodied. S1 and S2 indicated that the base could not be rotundate, S2 made an iconic gesture for this

concept by making a "C" in the air using the thumb and index finger of the left hand (Form 21), thus visualized the rotundate concept. However, S1 said that the base are closed and has positioned his left hand to be closed and the flat palm of left hand has been positioned facing the floor (Form 22). The student visualized the flat palm of the hand as the base. The surface of the hand a closed area was thought as to be close of the base. This movement for the close concept was a metaphorical metaphoric gesture. It was metaphoric gesture that the close concept which is abstract concept was represented with the whole of the hand and that display of closed place was shown on the base.

The students entitled the base as the bottom, upper base and the extreme of the prism. Both students showed the bottom and upper bases by the gestures (Forms 23 and 24). The upper base was shown by an iconic gesture in which the right hand was at the above and the flat palm was facing down. However, it was sign language that right hand was shown at the above for the upper base. Similarly, for the bottom base, the students positioned the flat palm of their left hand as looking at the upward. It was the iconic gesture that flat palm was thought as the base of the flat palm, whereas it was a movement in sign language that its shape was made at the bottom of the bottom. The gestures in Forms 23 and 24 were accompanied by the sign language.

Table 2. *Categories and gestures about base of prism*

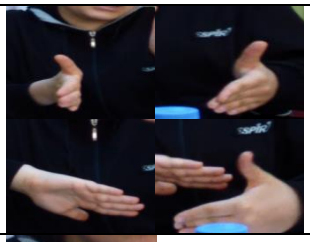
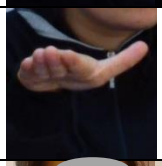
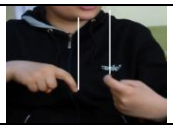
Categories	Sub-categories and dimensions		Gestures	Forms- Students-Type of Gestures
Being geometric shape	Square, rectangle, pentagon, hexagon, octagonal, polygon, no round (S1)			
	Triangle, square, rectangle, no circle (S2)			
Inclusion of geometric concept	Edge	Not one edge (S2)		Form 18 (S2)- Iconic ve ideograpic gesture
		Not two edges (S2)		
		Three, four, five, six, seven, eight, nine edges (S2)		
		At least four-sided (S1)		
Physical appearance	Smooth (S1, S2)			Form 19 (S1)- Metaphoric gesture
				Form 20 (S2)- Metaphoric gesture
	Not rotundate (S1, S2)			Form 21 (S2)- Iconic gesture
	Closed (S1,S2)			Form 22 (S1)- Metaphoric gesture
	Bases are the same (S2)			
	Quadratic region (S1)			
Nomenclature (S1, S2)	Upper base (S1, S2)			Form 23 (S1, S2)- Iconic gesture ve sign language
	Bottom base (S1, S2)			Form 24 (S1, S2)- Iconic gesture ve sign language
	The extreme of prism (S1)			
Expressing with a different geometric concept (S1)	Surface			

3.2. Findings about Surface of Prism

The students mentioned that the surface contained geometric shape, the number, physical appearance of the surface, lateral surface and formation (Table 3).

Table 3. *Categories and gestures about surface of prism*

Categories	Sub-categories and dimensions		Gestures	Forms- Students-Type of Gestures
Contains of the geometric shape	Edge (S1)	At least four-edged		

Number of it	At least six (S1)			
	Six with bases (S1)			
Physical appearance	Close (S1, S2)			Form 25 (S1)- Metaphoric gesture
	Quadratic region (S1)			Form 26 (S1)- Iconic gesture
Having lateral side		Lateral surface (S2)		Form 27 (S2)- Iconic and Metaphoric gesture
	Contains of the geometric shape (S2)	Triangle (in triangle prism)		Form 28 (S2)- Metaphoric gesture and sign language
		Square		Form 29 (S2)- Metaphoric gesture and sign language
		Rectangle		Form 30 (S2)- Iconic-Metaphoric gesture
	Having geometric shape (S2)	Edge		
	Its properties (S2)	All of them are different		
Creating	Creating from corner (S1)			Form 31 (S1)- Iconic and Metaphoric gesture

S1 who said that the number of the prism surface was six with bases at least four-sided, pointed out that the surface had at least four edges. Although she stated that the base was a surface, her gestures in Forms 13 and 14 showed only the lateral surface as the surface and didn't show the bases as the surface. S1 who indicated that the surface was closed only supported this situation by the gestures (Form 25). She used her right and left hand while she was telling that lateral surface was closed. The entire hand represented close concept and that the hands were shown on the right-left, front-back sides represented lateral surface which was closed, and so the surface was given a direction. For this reason the gesture was called metaphorical. However, S1 represented the flat palm as a quadratic region squares region, keeping the hand straight (Form 26). S2 used lateral surface concept for the side part of the prism and she showed it by the gesture in Form 27. S2 did the same gesture like Form 25, but unlike Form 25, the gesture in Form 27 was accompanied by the "lateral surface" discourse. S2 said that this lateral surface could be triangle, square and rectangle. In Form 28, the student made a triangle in the sign language using the index and middle fingers of right hand and index finger of the left hand. S2 showed it on the lateral part of the prism. In Form 29, the student made a square and showed it on the lateral part of the prism. These movements (in Form 28-29) were called metaphoric gesture. In

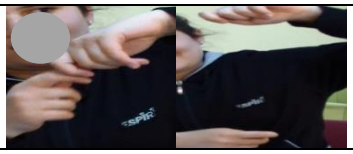
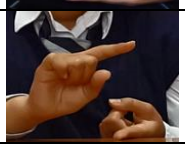
Form 30, S2 made square in sign language, then she did iconic gesture for rectangle while index finger of the left hand was moving from the right hand along one direction. However, this gesture was shown on the lateral part of the prism using metaphoric gesture.

S1 used index fingers of the right and left to indicate that the surface was formed by lines drawn from the corners (Form 31). Fingertip was moved from top to bottom along same direction in Form 31. When S1 touched the area which was represented as corner, S1 drew a shape which had two edges to represent a rectangle or square in the air while fingertip was moving from top to bottom. This gesture was an iconic gesture for "surface". Also, for the corner of the surface, the fingertips were used and represented the corner of the prism. In this gesture, an iconic gesture was made by representing the corners with fingertips, also, an metaphoric gesture was used by representing the points where the corners were located in the air.

3.3. Findings about Height of the Prism

The students mentioned of number of height, physical apperance, length, to be distance and to express by a different geometric concept (Table 4).

Table 4. *Categories and gestures about height of the prism*

Categories	**Sub-categories and dimensions**	**Gestures**	**Forms-Students-Type of Gestures**
Being different geometric concept	Edge (S1)		
	Lenght (S1)		Form 32 (S1)-Metaphoric gesture
Being number	Four (S2)		
	Six (S1)		
physical apperance	Smooth (S1)		Form 33 (S1)-Metaphoric gesture
	All of Height are the same (S2)		
	Not skew, being straight (S1)		Form 34 (S1)-Metaphoric gesture
	Perpendicular Straight (S2)		Form 35 (S2)-Iconic ve Deictic gesture
	Not short (S1)		
	It can be short or tall (S2)		
Being distance	Distance between up and down (S1)		
	Distance between upper base and bottom base (S1)		Form 36 (S1)-Metaphoric gesture
Being lenght	Being short (S2)		Form 37 (S2)-Metaphoric gesture

	Being tall (S2)		Form 38 (S2)-Sign language

S1 said that height was edge and length while talking about height. She made touch thumb and index fingers of right and left hands to each other, and then these hands were removed from each other along a vertical line while S1 was saying that height was a length. When the length was indicated by her, the right and left hands were closed and the sign and thumb and hand were touched together and then the hand was removed from each other along a vertical line. With this movement, the student has gestured to draw a straight line in the air vertically (Form 32). This was a clear proof that the student thought that the height were in a vertical direction. This gesture in Form 32 was a metaphoric gesture because it was the visualization of an abstract mathematical concept rather than a concrete context. S1 has indicated that height was smooth and did same gesture like Form 32. In Form 34, hands were positioned as not perpendicular to the base in the air. S1 said that height must not skew while she was making gesture in Form 34. This gesture was called metaphoric gesture because it visualized skew concept, an abstract mathematics concept. The student tried to mean that height should be perpendicular, but she did not use perpendicular concept, instead of this, she used that height should not be skew. Instead of being perpendicular, the concept of not being skew has been used, and although it could not express it correctly, it has showed a model in mind with the gesture it has done. Although S1 couldn't explain verbally that height should be perpendicular, S2 could express it with both gesture and speech. S2 made "L" shape using thumb and index fingers of the right hands in the Form 35. This movement referred perpendicular concept. The fingers which she made "L" shape made was shown with the left hand index finger. While the sign with right hand fingers was metaphoric gesture, the movement with left hand index finger was deictic gesture. In Form 36, S1 held that right and left hands were parallel to each other and told that height was distance between bases. This movement was also a metaphorical gesture. S2 said that height might be tall and short and made signs in Forms 37-38. In Form 37, it was shown distance between the right and left hand index fingers. This movement was a metaphoric gesture for "short height", but in Form 38, tall concept was made in sign language while distance between the fingers was keeping longer.

3.4. Findings about Prism Example

When asked to give a prism example relation to objects which the students saw around them, they gave prism examples and non-prism. S1 said that it was a prism in the form of a fruit juice box and a cupboard which were filled inside, out of place, no space anywhere and all sides were closed. S1 also represented the fruit juice box using the fingers of his right hand and left hand. S2 stated that the school was prism in order to be flat, and said that the table and glass were not prisms. She said that the table was not prism because it was small and prism had to be big. The glass was not prism because the bottom and upper bases were rotundate. In this process, there was a dialogue between S2 and the researcher as follows.

R: *…Other example?*
S2: (She is showing a glass in the room)*Is this prism?*
R: *I am asking you, is this prism?*
S2: (She is looking carefully to glass) *Yes.*
R: *Why?*
S2: *I don't know.*
R: *Why?*
S2: *Rotundate* (Figure 1a-b: showing upper and bottom bases of the glass) (Smiling) *It was wrong. Rotundate* (Figure 1c), *rotundate (*Figure 1d) (moving her hands both from bottom to upper, upper to bottom) *it is not prism. Rotundate* (drawing a rotundate with index finger in the air) *it must be straight* (drawing straight line in the air).

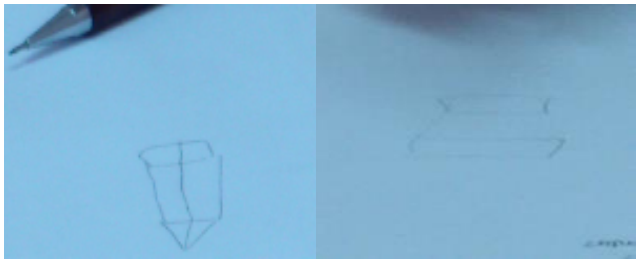
a b c d

Figure 1a-d. *Rotundate gestures (iconic, deictic and metaphoric gestures)*

Student who said that the glass was not a prism pointed out upper and bottom of the glass and made a deictic gesture. At that time, she said "rotundate". While she was saying rotundate, she made "O" shape using the thumb and index fingers of the right hand and this movement was repeated in the areas in where the bottom and the upper were. The bases were depicted with the rotundate gestures in Figures 1c-d and tried to be shown at the up and down along the vertical direction. In this way, iconic gesture was used in Fig. 1c-d. S2 stated using gestures in the air that it was necessary that the shape should be flat to be prism. In the glass, the student focused only on being rotundate of the bases' geometric shape.

In the above dialogue, S2 focused only on being rotundate of the bases' geometric shape. In a different dialogue, S2 stated that shapes in the bottom and upper bases must be same and these shapes must have the same size. The following conversation has passed between S2 and the researcher who think that bases of the prism should be the same.

R: *Is it possible that bottom base of the prism are square and upper of the prism is triangle at the same time?*
S2: (drawing Figure Şekil 2a) *No. …There are three edges in the triangle, 1, 2, 3* (making triangle in sign language using fingers and counting them) *There are foru edges in the square. It is not.*
R: *How much must it be?*
S2: (pointing out triangle in Figure 2a by index finger) *Four edges.*
R: *Ok. Is it possible that bottom base of the prism are square and upper of the prism is rectangle at the same time? There are four edges in the rectangle.*
S2: (drawing shape in Figure 2b) *No.*
R: *Why?*
S2: *Rectangle* (pointing out the upper base in figure 1b using index finger of the right hand) *is big* (opens her two hands with his palms facing each other), *square is small* (the two palms are less open than the first, with palms facing each other) *it is not.*
R: *Ok. There is small square on the bottom base and big square on the upper base. Is it possible?*
S2: *It must be small* (the two hands are open with palms facing each other) *square* (moves her hands from the up to down in the same direction) *Small, small square* (making gesture in Form 6).



a b

Figure 2. *Non-prism shapes drawn by S2*

The student was asked to say whether the shape which its upper base was triangle and its bottom base was square was a prism. The student drew the shape in Figure 2a and stated that the shape was not a polygon because the triangle had three edges and square had four edges. The student said that triangle could be a prism in the case of four edges. The researcher then questioned whether the shape was prism if the bases were rectangle and square. On this case, the student drew the shape in Figure 2b, she said that the shape was not a prism indicating that rectangle was big and square was small. The student explained using sign language that the rectangle was big. She opened her hands the way to look at each other. She made metaphoric gesture to show small concept. In fact, the student tried to say that the bottom and upper bases had to be formed from the same shape, but she could not express it clearly. And then, the researcher asked whether the shape was prism that both bases were square, but one of the squares was big, the other was small. The student stated that it could not be prism again. When it was asked why the shape was not a prism, the student said that squares in both bases had to be small using gesture in Form 6. Then, the researcher wrote 2 cm and 5 cm on the edges in the bottom and upper bases and asked the students whether the shape was a prism. The student said that the shape was not a prism because their edges were different, not same and edges had to be same. In fact, the student tried to express that the lenghts of the edges had to be same, but she could not explain it with the appropriate words.

4. Conclusion and Discussion

In the present study, students were asked to explain the concept of prism, its features and give an example and it was investigated how the gestures were included to the explaining process of the concepts related to prism and which gestures were used by the students. It was determined that the students defined prism as three dimensional object which had base, surface and height and the students used iconic, metaphoric and deictic gestures in this process. One movement sometimes had more than one gesture.

One of the elements that enables to be organized the cognitive resources for better resolution of a given task is gesture (Goldin Meadow, Nusbaum, Kelly, & Wagner, 2001). In the present study, it was determined that students' gestures used in the process of defining prism and characteristics were an important source of information in the transferring abstract thoughts of individuals. For example, it can be seen that all of the prism gestures of the students were made vertically upwards or downwards. In other words, students have placed the base vertically on the upper and bottom surfaces in all prisms, and have not placed them in the front-back or right-left position in the horizontal direction. As it can be seen from these gestures, for hearing impairment students, prism is a geometric object where the surfaces that are identical and parallel to each other are located only vertically. Similarly, it has been determined that students showed height in vertical direction in all of the gestures made for prism. The height shown as limited two ends and straight line is expressed along the vertical direction in the entire prism. However, the distance between both bases represented the height of prism and height can be perpendicular line segment on the horizontal direction. Because the students showed the entire prism along the vertical direction, the students can be to show height along the vertical direction. However, the students said that the bases of the prism should be regular. But, the students didn’t use regular concept within the meaning of regular polygon which measurement of its angles and the lengths of its edges are the same, they used within the meaning of the “straightness”, “not being curve”. This situation was understood from their gestures (Form 19-20). Because, S1 held flat the bases shown in the vertical direction in the Form 19 in a straight line, S2 made the thumb and index finger of the right and left hand in the form of "o", then fingers of the hands were send away from each other in the Form 20. With this movement, a straight line was drawn along a horizontal line in the air. These gestures also provided us some clues related to regular concept in the student's mind. If it was taking into only her spoking about the regular concept, it can be said that she mentioned about regular polygon. However, the gesture accompanied speaking clearly revealed construction in her mind. This finding supported thought that gestures reflected the inner thoughts of people (Alibali, Bassok, Solomon, Syc, & Goldin-Meadow 1999; Garber & Goldin-Meadow 2002; McNeill 1992; Wilson 2002). Contrary to this thought, Kita (2000) claimed that the gestures were caused by visual actions in the visual area of

the discourse. According to him, the gestures were expressed as a visual action rather than revealing the mental image.

Another result obtained in the present study is that it is possible to concretize information that is not explained by speech through gesture. For example, none of the students said that the bases of the prism should be parallel to each other, but they hold bases as parallel with each other in all the gestures made for prism or base by them. Something that is difficult to say or not expressed by speaking can be explained more easily by the gestures. It can be thought that students were not aware of the parallel of the bases other if only his speech which was not mentioned that the bases were parallel to each other was taken into consideration. However, S1 should not be able to say verbally that the height should be perpendicular, but she emphasized that the height should be perpendicular with the gestures made related to regular or not skew. Sabena (2004) stated that gestures provide an alternative information organization in situations where analytical thinking can not be achieved easily. Goldin-Meadow, Nusbaum, Kelly, and Wagner (2001) asserted that the gesture could make it possible for the speaker to reach a temporarily unavailable verbal clause, thus facilitating the processing of speech. So, Arzarello et al. (2009) stated that gestures provide an alternative way for students to organize or concretize information in cases where the students are difficult to express only verbally or in a formal way, supporting students' thinking processes. The finding in the present study also supported all these views.

It has been found that students have either missing or incorrect information about prisms. This situation was detected by the speech or gestures. In the process of explaining the prism, the students mentioned the elements such as base, surface (lateral surface), height, but did not mention features such as object or surface diagonal, height of lateral surface. Regarding the corner, only S1 mentioned from corner concept while she was explaining how the surface was formed. Both of the students said that the prism had edges (“kenar” in Turkish). But, geometric objects have edge (“ayrıt” in Turkish) not edge (kenar). Because, the edge (kenar) is the ray or line segment that determines the boundaries of a shape (Hacısalihoğlu, 2002), edge (ayrıt) is the intersection of the two planes (Güler and Yücelyiğit, 2011). Prism is expressed in three dimensional space, and the all of surfaces is expressed in two dimensional plane. The intersection of the planes in which bases are situated explains lateral edge (ayrıt), not edge (kenar). Also, S2 did not know that the lateral surfaces need to be equal, she said that all of the lateral surfaces are different and lateral surfaces could be triangle, square and rectangle. S1 did not comment on this situaation. However, the lateral surfaces can not be triangle, they can not be only square or rectangle. For example, in the skewed prism, lateral surfaces indicate a parallelogram region (Güler & Yücelyiğit, 2011).

The results of the research show that hearing impaired students often use their gestures in the process of engaging in mathematics. Therefore, the need to sign these students can not be discussed. These signs presented various clues about the structure of their minds. Because of this, it can be suggested that teachers should use hand, arm and body movements in the process of embodying concepts in classroom practices in the present study.

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