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9TH Grade Students' Mental Models about the Sound Concept

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ABSTRACT

This study aims to determine the mental models of 9th grade pupils regarding sound and the dispersion of sound. The sample consists of total 30 9th grade pupils (18 female and 12 male) studying in secondary school in Turkey. A semi-structured interview form was used as the data collecting tool and descriptive method of the findings. The findings are indicated that students are trying to establish a relationship between sound source, the propagation medium and the receiver for as the dispersion of the sound. Also, there are shapes as global spread of the sound, spread up into space of the sound and the waves of circular of sound, and spread of the sound based on vibration of the atoms in students drawing. As a result of the study four different mental models related to sound concept were identified: wave model, mechanical model, matter-based model, and artificial model.

Key words: dispersion of sound, secondary school students, mental models

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INTRODUCTION

The importance of model and modelling in science education in terms of its enabling the concepts within the sciences to be accessible and comprehensible cannot be ignored. Models take on a task of bridge between the scientific theory and the real world; models can be a simple indication of the real to make an observation or the source of scientific explanations about a phenomenon and predictions (Gilbert, Boulter and Rutherford, 2000). In literature, models are approached as conceptual and mental models (Gilbert et al. 2000; Gunes, Gulcicek and Bagci, 2004; Ornek, 2008; Unal and Ergin, 2006). Generally accepted and shared by scientists and being models having the suitability with the scientific knowledge of the society, conceptual models include mathematical, visual, physics and computer models. As for mental models, being an inner representation indicating structural similarities of events or processes, they are created by reinvigoration of concepts and processes within the mind (Norman, 1983). According to Norman (1983), mental models are incoherent and inherent knowledge having no scientific accuracy and not completed according to the standard knowledge and mental models different from each other can be created for a system. According to this, it can be said that mental models are peculiar to the individual and they develop as new knowledge is acquired. The main function of mental models is to allow the individual to forecast and explain about the represented real (Gilbert et al. 2000; Greca and Moreira, 2000; Greace ve Moreira, 2002; Johnson-Laird, 1983; Norman, 1983; Vosniadou and Brewer, 1992). In relation to this situation, different individuals can be expected to create different figures about the same concept in accordance with their interaction with the world they live in (Nersessian, 1992). Mental models can give an opportunity to evaluate how concepts are grasped, to what extent knowledge is structured and to what extent the individual can develop his/her mental talents. In addition to this, having knowledge about mental models is significant in education and training in terms of its being helpful for us to grasp why misconceptions and alternative concepts resist the change (Ünal ve Ergin, 2006).

In literature, concept of sound, having an important place among concepts of physics, has been discussed within numerous researches (Coombs, 2007; Hrepic, 2002; Hrepic, 2004; Hrepic, Zollman and Rebello, 2002; Maurines, 1993; Wittmann, Steinberg and Redish, 2003) about mental models of students. Sound is the most important factor of interpersonal communication in daily life; and in the field of physics, it is a subject area that contributes the topics of approach of particle offering an insight to the phenomenon of wave, energy and transfer of momentum to be understood. As in other concepts of physics, identification of mental models for the concept of sound can be important in terms of learning. Besides, it must be considered that what students have already mislearned or they will probably mislearn will affect other

learning; consequently, success of the student. For that purpose, within the scope of the study, based upon students' verbal explanations and visual drawings about propagation of sound, their mental models for the concept of sound are tried to be identified.

METHODOLOGY

In this study, descriptive method has been used with the aim of identifying students' mental models for propagation of sound. Studying at a college, 30 students in total from secondary education 9th grade students, 18 of whom are female students and 12 of whom are male students, make up the sample of the study. In this study, students have been chosen at random and principal of voluntariness has been taken into consideration.

Data Collection Instrument and Data Analysis

In this study, with the aim of revealing students' mental models regarding how sound propagates, a semi-structured interview form consisting of 3 questions has been used. Descriptive method analysis has been used in the study and students' common and different views for each question regarding propagation of sound have been coded. Categories have been formed by researchers comparing similarities and differences between the expressions of students regarding propagation of sound. Frequencies specified in the table have been taken through the codes that students have specified. In addition, some of the sentences summarizing the main idea in the explanations of students have been presented in quotes without impairing their originality. Students, whose views have been quoted in exactly the same way, have been respectively symbolized as S-1, S-2, S-3, ... and S-30.

RESULTS

Findings obtained from the study have been presented in 3 subtitles as propagation of sound, drawings regarding propagation of sound and mental models for propagation of sound.

Propagation of Sound

Explanations and drawings of students regarding propagation of sound have been analyzed separately. Explanations of students regarding propagation of sound are shown in Table 1.

Table 1. Explanations of Students regarding Propagation of Sound

	Propagation				Receiver	f
	Medium	Manner	Distance	Velocity		
Source of sound	It is transmitted well in solids.	In waves	As going away from the source, the loudness level decreases.	As the density of medium changes, it changes as well.	Particles of air	7
	It is different in solids, liquids and gases.	In the form of expanding waves	It is sharpest when it first comes out of the source, it decreases gradually.	It propagates more slowly than light.	Air	6
	It doesn't propagate in space.	Free	If the distance between two individual increases, it cannot be heard.	As the distance increases, the velocity decreases.	Atoms and ear	2
	It is transferred very well till it encounters an obstacle.	Like water waves	If the distance increases, the sharpness decreases.	If there is an obstacle, the velocity decreases.	Particles of air	2
	If there is an obstacle, echo exists.	According to a certain order	If the distance between atoms making up the medium is short, it propagates well.	As the density of medium increases, its velocity increases as well.	Atoms	1
	Medium with particles	In waves	As the distance between particles increases, the velocity decreases.	It gets easy in dense medium.	Particles of air	1
	It changes depending upon particle density.	Wavy and crashingly	As going away from the source, it becomes hard to be heard.	It decreases gradually depending upon time.	Particles of air and ear	5
	Propagated in outer space	Interaction of vocal cords	It lasts forever.	It affects the amount of propagation of sound.	Ear	2
	Anaerobic medium	Vibrating	If the distance between particles of medium is long, it propagates well.	Different from the particles of the medium	Ear	1
	It is transferred in the best way in gases.	In the form of waves, vibrating each other	If the distance between particles is long, the transfer is good.	The longer the distance between atoms is, the faster it is.	Air	2
	Thanks to the spaces existing in matters	In the form of vibrating waves	As approaching the source, loudness level increases.	As the density of medium changes, the velocity of propagation changes as well.	Atoms	1

In Table 1, it is seen that students try to correlate among source of sound, medium of propagation and receiver regarding how sound propagates. While nearly half of the students have expressed sound equipment and voice as source of sound, some of them have expressed human as source of sound and some have expressed only sound equipment. Besides, it is seen that all of the students have expressed that sound is propagated depending upon the properties of medium while propagating, distance between source of sound and receiver has an effect on sound propagation and this effects the velocity of sound.

In Table 1, it is seen that all of the students have used expressions regarding the particles of medium, the velocity of sound and the form of propagation of sound while the sound propagates. It is seen that a quarter of the students have expressed that sound is transferred well in solids, it is propagated in waves while transferred, its sharpness decreases as it goes away from the source and its velocity is to change depending upon the density of medium. A few of the students express that sound cannot be propagated in space and that the more the distance from the source increases, its velocity decreases and for that reason it cannot be heard; some students express that sound can be propagated in outer space and continue forever. A few of the students have expressed that sound is propagated in the best way in gases, it will go further in waves vibrating each other and that the longer the distance between atoms is, the faster it propagates; and some students have expressed that sound will go further at different speed in solids, liquids and gases, it moves forward in the form of sound waves and it propagates more slowly than light. Some students have expressed that the propagation of sound changes depending upon the density of particles and it gradually decreases depending upon time; few students have expressed that sound will be transferred till it encounters an obstacle, it goes forward like water waves and that the longer the distance is, its sharpness will decrease.

Some of the expressions that the students have made for the question "How does the sound propagate?" are presented below:

"Sound comes out as a force from its source and it comes out by motivating the particles in the medium with particles. That is, force converts into sound energy. Sound is transferred in the fastest way in solid medium, more slowly in liquid one and in the slowest way in gas medium. As for the space, it doesn't propagate." (Ö-7)

"Waves are formed by the vibration in the matter. The propagation of these waves into the surrounding area enables the propagation of sound. It doesn't propagate much in dense medium. The longer the distance between particles is, the easier the propagation of the sound gets. It can propagate to the further places. (Ö-12)

"Sound propagates as a result of atoms' stimulating each other by vibrating. The propagation of sound can change according to the medium. For instance, as the atoms of solid substances are attached more tightly to each other, the sound propagates in a better way. As for the space, it doesn't propagate." (Ö-13)

"It propagates in different forms in different medium. While propagated in the fastest way in solids, it propagates more slowly in the liquids, and in the slowest way in gases. Also, sound can propagate at different speed and sharpness according to the source it comes out of." (Ö-21)

"Sound is propagated in air in the form of waves. Sound, propagating via vibration movements, propagates in waves in air. These waves change according to the presence the sound is formed in. For instance, sound is propagated in radio waves in radio. As for the sound formed by human-beings, it propagates as a result of vibration movements." (Ö-25)

Drawings regarding the Propagation of Sound

The drawings of the students regarding the propagation of the sound are shown in Figure 1.

In Figure 1, it is seen that all of the students try to summarize their views they have expressed by making drawings regarding how sound is propagated. Drawings above show that there are differences within the students' drawings regarding the propagation of the sound along with similarities. It is seen that while the majority of the students make similar drawings regarding the fact that sound is propagated spherically, different drawings, even if in minority, have been made regarding the propagation of the sound in the form of circular waves like water waves and with the help of figures grounding on the vibration of the atoms.

Mental Models Regarding the Propagation of the Sound

It has been tried to identify the students' mental models regarding the propagation of sound considering all the answers that students have given to the interview questions and drawings. It has been seen that the majority of students have the wave model and the minority of the students have mechanical model, matter-based model and synthetic model. While these models are identified, models existing in literature and also their properties have been considered. In wave model, sound is propagated through particles of medium and it is the longitudinal vibration of particles of medium. Hrepic (2002) also expresses the transfer of sound via particles of medium and vibration of particles of medium with wave model in his study. As for mechanic model, it is a theoretical model consistent with scientific knowledge.

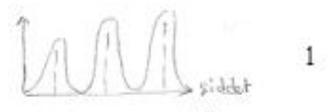
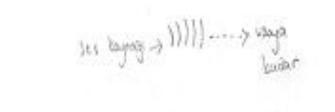
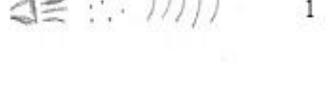
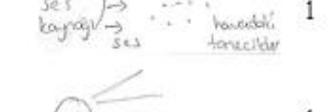
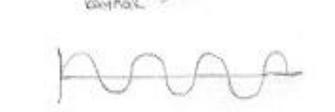
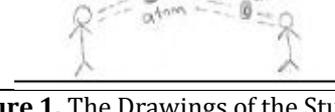
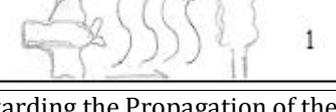
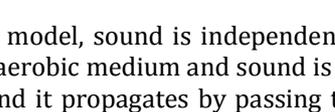
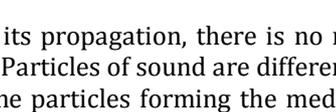
Drawing	f	Drawing	f
	8		1
	3		1
	2		1
	1		1
	1		1
	3		1
	3		1
	1		1

Figure 1. The Drawings of the Students regarding the Propagation of the Sound

In matter- based model, sound is independent and for its propagation, there is no need for medium. It propagates in anaerobic medium and sound is a matter. Particles of sound are different from the particles of the medium and it propagates by passing through the particles forming the medium. The longer the distance between the particles is, it propagates in a better way. Hrepic (2002) also underlines the fact that sound is independent, it can propagate in anaerobic medium, sound is a matter having mass and volume and he expresses the propagation of the sound particles of the sound different from particles of medium with matter-based model. As for synthetic model, it is the combination of the knowledge regarding matter-based and wave models. While the combination of misconceptions or lack of knowledge and scientific knowledge is expressed as hybrid model (Hrepic, 2002); in the studies of Vosniadou and Brewer (1994) and Vosniadou and Brewer (1992), it has been expressed as synthesis model. In the studies of Vosniadou and Brewer (1992) and Greace and Moreira (2002), hybrid model is expressed as beginning model that the students have formed depending upon their preliminary knowledge. From these mental models, though wave model and mechanic model is scientifically consistent with the propagation of the sound, as for matter-based model and artificial model, this situation is out because, in these models, misinformation of the students, their misconceptions or lack of knowledge and the combination of scientific knowledge are the subject.

In wave model; students have expressed that sound is transferred via the vibration of atoms, everything living-beings and non-living things can be sources of sound, it depends upon the wave frequency of loudness level at unit of time, sound is formed by the vibration of molecules in air and sound is propagated at different speed in different mediums. For example, the view of the participant (S-19) as "Sound, after light velocity, is the fastest vibration. Sound can propagate at different speed and sharpness according to the source it comes out of. It can propagate in waves. Its sharpness is the highest at the first moment of its coming out of the source. As it propagates, the sharpness decreases. It propagates fast in the medium where the particles of sound are close to each other and in the medium where the particles of sound

are away from each other, it propagates slowly." is in a supporting feature of this model. Similarly, drawings of the students (drawing: 1, 4, 5, 6, 7, 9, 11 and 16) support this model.

In mechanical model; students have expressed that sound is formed by vibration movement and it is strong, everything that leads to collision and friction can be the source of sound, it is propagated at different speed in different medium, sound frequency is the adjustment in the wave length of sound, it gets energy via the vibration of atoms, it proceeds through the clashing of particles in air to each other, it needs particles of medium for energy transfer and it is the wave that vibrates longitudinally. For example, the view of the participant (S-27) as *"Sound is the energy formed by the interaction of our vocal cords and it propagates in waves. The constituent of a matter is atom. Energy comes out as a result of interaction of electrons in the atom. What the energy of electrons means is the sound energy. Sound propagates in every medium except space. Nevertheless, it propagates at different speed in every medium. It propagates at most in solids."* is in a supporting feature of this model. Similarly, drawings of the students (drawing: 8, 10, 12, 13 and 15) support this model.

In matter-based model; students have expressed that sound can propagate in outer space, living – beings can be the source of sound, sound frequency depends upon the amount of the propagation of sound and sound is formed by the crashing of air to the vocal cords. For example, the view of the participant (S-2) as *"Sound doesn't disappear and it causes the reaction. It is a presence that arises from the vibration movement and has strength. It is carried by air particle, it doesn't propagate in space."* and the view of the participant (S-10) as *"Sound, propagating in waves, is a presence that people can perceive those at certain frequency."* are in a supporting feature of this model. Similarly, drawings of the students (drawing: 2) support this model.

In artificial model; students point out that sound is the vibration and transfer of air molecules, living – beings that lead to vibration and the nature are the sources of sound, sound frequency depends upon the vibration that sound forms at unit of time, sound reaches the position that will affect every atom with the decreasing of kinetic energy that sound has and it can propagate in anaerobic medium. Besides, they have expressed that sound moves around by collision and friction, its velocity changes according to the density of the medium, it is formed by the crashing of the particles in air to each other and it goes forward in expanding waves. The view of the participant (S-8) as *"Sound propagates in sound waves. It is formed by the crashing of air particles to each other. Sound propagates more slowly in solids. Therefore, it gradually loses its energy. It is transferred in the best way in gases because the particles in gases are very distant from each other. For that reason, the sharpness of the sound doesn't decrease much."* and the view of the participant (S-23) as *"Sound is the energy emerging with certain vibrations. It doesn't propagate in space. It never disappears, continues forever. It propagates in waves. It is formed by crashing of the particles in air to each other. Sound propagates more slowly in solids. Therefore, it gradually loses its energy. It is transferred in the best way in gases because the particles in gases are very distant from each other. For that reason, the sharpness of the sound doesn't decrease much."* are in a supporting feature of this model. Similarly, drawings of the students (drawing: 3 and 14) support this model.

DISCUSSION AND CONCLUSION

In this study, mental models of the students, studying at 9th grade in secondary education, have been tried to be identified by analyzing students' expressions and drawings regarding how sound propagates. The fact that a group of students think sound propagates depending upon the properties of medium while propagating by correlating among source of sound, medium of propagation and receiver have been identified. Another group of students have mentioned that the distance between source and receiver has an effect upon the propagation of sound and it affects the velocity of sound. Yet, some of the students have expressed that sound propagates in space, it moves like water waves, it proceeds thanks to spaces in matters, its velocity decreases in dense medium and that the longer the distance between the atoms is, the faster it propagates. This finding indicates that students correlate the propagation of sound with water and light waves. Maurines (1993) has stated that students have misconceptions in the direction that there is no need of medium for the sound to propagate, sound can propagate in space and that as the density of medium increases, the propagation of sound gets difficult. Project of American Institute of Physics (1998) has asserted that students have misconceptions as sound, in air, moves faster than solids, sound moves in space area among matter particles rather than matter and the movement of sound waves is longitudinal itself.

It has been seen that 19 of the students have wave model, 5 of them have mechanical model, 3 of them have matter-based model and 3 of them have artificial model. Although wave model and mechanical model are scientifically consistent with propagation of sound, this case is beside the point in matter-based model and artificial model because misinformation of students, their misconceptions or lack of

knowledge and combination of scientific knowledge can be in question in these models. This situation is related to the fact that mental models include contradictory constituents, they don't have scientific accuracy and they are incoherent and inherent (Gilbert et al. 2000; Greca and Moreira, 2000; Greace ve Moreira, 2002; Johnson-Laird, 1983; Norman, 1983; Vosniadou and Brewer, 1992). In addition to the fact that a large majority of the students have a scientifically coherent and clear sense about the concept of sound, it is seen that there are also students who have misinformation or who doesn't have adequate knowledge. At this stage, it necessitates the analyzing of students' mental models passing after a teaching process peculiar to the topic as well as their mental models tried to be determined depending upon their preliminary information and the comparison of their early mental models and those after teaching. This situation will enable the opportunity of a wide range of evaluation about the students' mental models.

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