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Prospective science teachers' understanding of sound

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Abstract

The goal of this study is to describe prospective science teachers' (PST) conceptions about basic sound phenomena and concepts. The study was conducted on 56 PSTs. The questionnaire that is used as data collection instrument consists of 3 open-ended questions regarding sound production, the propagation and nature of sound. The results of the study show that PSTs encounter difficulties in understanding this fundamental topic.

Keywords: Sound; conceptions; learning; prospective science teachers

1. Introduction

In the last three decades, studies on the conceptions of students and teachers on various science content domains and their roles in learning science have been one of the most important fields of research in science education (Duit and Treagust, 2003). These studies show that pre-instructional knowledge or beliefs of learners about the phenomena and concepts to be taught are usually different from scientific knowledge and that these conceptions influence further learning and may be resistant to change (Driver R 1989); and what is more, teachers and prospective teachers as well as students have certain conceptions on the issue (Küçüközer, 2007).

There are many studies conducted to examine the conceptions in various domains of physics (mechanics, electricity, optics etc.). Nevertheless, it is obvious that the amount of research on sound waves is strikingly scarce (see Pfundt and Duit, 2007). The goal of this study is to describe prospective science teachers' (PST) conceptions about basic sound phenomena and concepts. The sound waves is of importance since it is the first topic in which the introduction is made to the subject of waves at the levels of primary and secondary education and the concept of wave plays a critical role in the learning of topics such as mechanic-electromagnetic waves, physical optics and quantum mechanics.

Studies on students' conceptions concerning sound show that students encounter difficulties in understanding this fundamental topic. These conceptions could be briefly summarized as follows:

- the production of sound is explained based on the physical properties of the source and the force needed to produce the sound along with the vibration of the sound source. Furthermore, the mechanisms of sound

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production are context-specific, and students lack a generalized understanding of sound production transferable across contexts (Asoko, Leach and Scott , 1991),

- students' understanding of the nature of sound is described through two different explanatory perspectives. In the microscopic perspective, the students explained sound as an entity carried or transferred by molecules with no inherent action of its own, whereas in the macroscopic perspective, they explained sound as a substance; that is, a continuity of form associated with a moving 'force' that had an inherent action of its own (Linder and Erickson, 1989; Linder, 1992)

2. Research Context and Methods

The study was conducted on 56 PSTs from the Department of Science Education at Necatibey Faculty of Education in Balıkesir University. PSTs did not take any course on the research subject at the undergraduate level.

The questionnaire that is used as data collection instrument consists of 3 open-ended questions regarding sound production (Q1), sound propagation (Q2, Q3). Q1 was adapted from the study by Asoko et al. (1991), whereas the 2 others are original questions. In the questionnaire students were asked;

- Q1: to explain how sound is produced when two stones are struck, the string of a guitar strummed and a drum is beaten,
- Q2: to imagine the air molecules between the speaker and the listener in a case where one of the two persons sitting opposite to each other is the speaker and the other is the hearer; to explain whether the air molecules would move during the propagation of the sound and, if they would do so, to draw and depict the movement of air molecules and explain your responses,
- Q3: to assume that they are on the surface of the moon and hear an enormous explosion happen somewhere close to the moon and explain whether they would see or hear anything and why.

The questionnaire was scrutinized by specialists, each on physics and physics education. The questions were tested through a pilot study administered to 5 students and then applied after the necessary changes were made.

Upon the analysis of the explanations and drawings provided by the PSTs, a distinction was made between those scientifically correct and incorrect at first hand. The scientifically incorrect explanations were then analyzed to classify into groups with different content and to determine the conceptions pertaining to each particular concept or phenomenon.

3. Results

The findings state that the PSTs have certain conceptions on the basic sound concepts and phenomena, which were then interpreted by representing the main results under relevant headings.

3.1. Sound production

PSTs explained sound production as a phenomenon based on action or physical properties of the source as well as vibration of the sound source. The explanation linking sound production to the vibration of the sound source varies in accordance with the context. Only 14% of the PSTs explain sound production on the basis of the vibration of the source for all contexts. Whereas the most and the second most frequently referred contexts about vibration are strumming the string of a guitar (59 %) and beating a drum (30 %), respectively, the least frequently referred one is striking stones (14 %).

PSTs often explained production of sound by striking stones (41%) as a result of the action, saying "with the striking of stones or when stones are struck, they exert a force to each other, which produces the sound". As for the context of drum (18 %), they rather tend to provide action-oriented explanations such as "action exerted on the surface produces the sound" or "sound is produced when two objects are struck together". The context with the least action-focused explanation is that of guitar string (7 %).

When compared to other contexts, the tendency to explain sound production on the basis of the properties of the sound source reaches to the highest degree in the drum context (16 %). The explanations obtained from the questionnaire are: "The string is taut", "the stones are hard", "there is air inside the drum" and "the surface of the drum is taut".

3.2. Propagation and nature of sound

The findings (Q2, Q3) indicate that PSTs were not able to describe the sound propagation correctly at the microscopic level, that they are not aware of the need for a material medium, and that their conceptual understanding of the propagation and nature of sound is far from being scientific. While only 7 % of the PSTs stated that the movement of particles within the medium during the sound propagation will be a vibrational motion, none of them made any reference to compression and rarefaction regions neither in their drawings nor in their explanations. Only 30 % of the PSTs stated that a medium is required for the sound propagation.

Regarding the motion of medium particles during the sound propagation, 4 different types of description were observed among the PSTs, which are vibration (7%), random motion (26%), collision (18%), moving away and divergence (11%). Approximately one-third of the PSTs stated that the motions of air molecules change during the sound propagation, but about the nature of this motion they do not have any idea to formulate either an explanation or a drawing.

It is seen that the ideas of PSTs about the nature of sound are quite discrepant with scientific understanding. They regard sound as an entity and about its nature they basically have three different approaches, which are listed as follows:

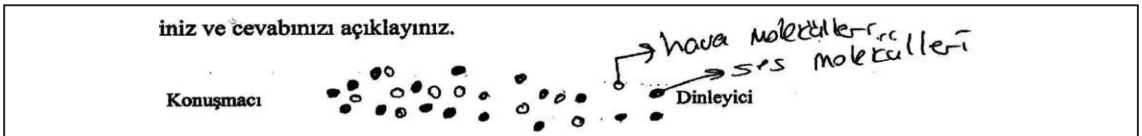
1. Sound is a substantial entity which can travel spontaneously without any need for a medium,
2. Sound is an entity carried and transmitted by the molecules of the medium,
3. Sound is an abstract entity that exists with its effects and travels without any need for a medium.

3.2.1. Material sound which travels on its own

Without any need for a medium, it moves towards the receiver on its own. The composition of this material sound could be of an intermittent or continuous form, which have varying effects upon the motion of medium particles. This structure is referred to as sound, sound molecules or sound waves.

3.2.1.1. Intermittent material sound

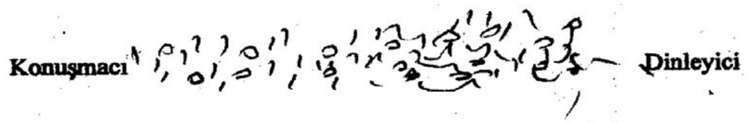
"Sound" is of an intermittent structure, it travels through the medium particles and affects the motion of these particles in a random, irregular manner as it meets them. As could be seen in the drawing and explanation in figure 1, this intermittent structure could be in the form of "sound molecules"



As the air molecules in the gas state, they are in motion. Sound molecules might come across these. However, since there is much more space in between gas molecules that will not be much affected when compared to solids and liquids.

Figure 1: The drawing and explanation by S50 (Q2, Konuşmacı: Speaker, Dinleyici: Listener, Hava molekülleri: Air molecules, Ses molekülleri: Sound Molecules)

or as shown in figure 2, it could be in the form of intermittent "sound waves" that can travel through the molecules of the medium.



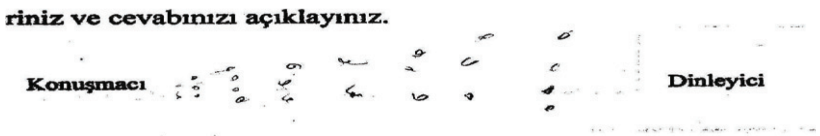
The air molecules move as the sound propagates. Because the sound waves emitted by the speaker are interposed between the air molecules, leading them to move.

Figure 2: The drawing and explanation by S52 (Q2)

Though it has the capacity to move the medium particles, intermittent sound cannot have a strong effect. 26% of the PSTs interpret the nature and propagation of sound within the framework of this approach.

3.2.1.2. Continuous material sound

The sound travels in a much more continuous form and while passing through the molecules of the medium, it fills the gap between and displaces the particles of the medium (figure 3)



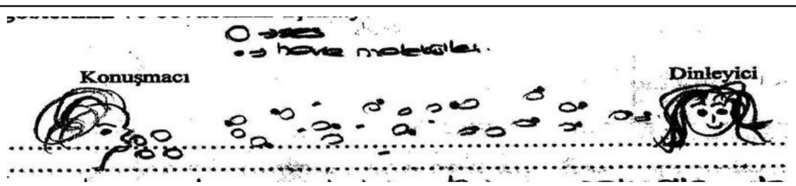
It moves, because there is an amplitude (that is, sound) moving through, which will inevitably affect the air molecules. They will diffuse with the sound.

Figure 3: The drawing and explanation by S2 (Q2)

or it separates the medium particles and pass between them like a wind or a flow of air. Continuous material sound manifests itself a volume-occupying structure with the capacity to exert a force and to do work. 11% of the PSTs interpret the nature and propagation of sound within the framework of this approach.

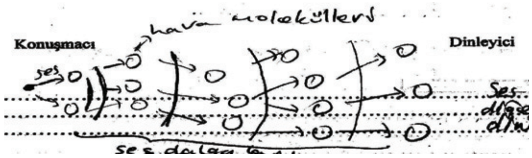
3.2.2. Sound as an entity carried and transmitted

It cannot travel on its own but needs a medium for propagation and it propagates by being carried by the particles of the medium and/or being transmitted with the collision of the particles. As seen in figure 4 and 5, this substance is transmitted, is carried and propagates through the collision of molecules



Air molecules move as well during the propagation of sound in air. It is actually the air molecules which play a role in the propagation of sound (in air).

Figure 4: The drawing and explanation by S42 (Q2, Ses: sound, Hava molekülleri: Air molecules)



Sound waves reach the listener by being transmitted from one molecule to another.

Figure 5: The drawing and explanation by S34 (Q2, Hava molekülleri: Air molecules, Ses dalgaları: Sound waves)

along with the formulation "sound molecules transmitted through air molecules", it could be expressed with the terms sound and sound waves and could also be of a microscopic structure. 18% of the PSTs interpret the nature and propagation of sound within the framework of this approach.

3.2.3. Sound as an abstract entity

In a conception where an unscientific understanding of phenomena and concepts prevails notwithstanding the use of physical terms learned, sound is observed as an intermittent entity that can travel without any need for a medium. As could be seen in figure 8, the particles of the medium vibrate, so to speak, simply as a natural result of the passing of sound waves, rather than a requirement for the propagation of sound.

Air molecules begin to vibrate during the crossing of the waves. Thus, a motion starts in the direction of sound

Figure 6: The drawing and explanation by S46 (Q2)

In the first approach, as the material sound propagated, it traveled between the particles of the medium, shifting them randomly. In this approach, it seems that sound is conceived as an abstract entity which travels throughout the medium as if the way was a line and the particles of the medium vibrate (for instance, figure 6).

4. Discussion and Conclusion

The results of the study indicate that PSTs have conceptions regarding the basic concepts and phenomena of sound. These conceptions can be summarized as follows:

- Sound production is explained based on action or physical properties of the source as well as vibration of the sound source and the mechanisms of sound production are context-specific.
- Three different ways of understanding of the propagation and nature of sound were identified:
  - Sound is a substantial entity which can travel spontaneously without any need for a medium. The composition of this material sound could be of an intermittent or continuous form. During the sound propagation, the motion of medium particles is random motion or moving away.
  - Sound is an entity carried and transmitted by the molecules of the medium. During the sound propagation, the motion of medium particles is collision.
  - Sound is an abstract entity that exists with its effects and travels without any need for a medium. During the sound propagation, the motion of medium particles is vibration.

Among these conceptions, in addition to those consistent with findings of the literature, there are also ones, in our knowledge, identified for the first time. Concerning the conceptions of sound production, the results above coincide wıith the results of Asoko et al. (1991). Regarding the ways of understanding of the propagation and nature of sound, previous studies (Linder et al., 1989; Wittmann et al., 2003) have already stated that sound is conceived as a entity, rather than a wave. The conception "sound as an entity transmitted and carried" is consistent with the conceptualizations of sound put forward by Linder et al.(1989). However, the way of understanding of sound as abstract entity that exists with its effects and travels without any need for a medium has not been identified so far. Regarding, the result "material sound which travels on its own" is partially similar to those of Linder et al. (1989), especially "intermittent material sound" approach has not been identified so far.

The PSTs constituting the sample group of this study did not receive any education about the subjects of waves and sound at the undergraduate level. Yet, studies conducted on the samples consisting of students receiving a typical education at the undergraduate level (Linder et al., 1989; Wittmann et al., 2003) display similar results. It is a question of importance the lack of and necessity to develop educational materials to be prepared for every educational level in the framework of constructivism taking into account the conceptions of students, aiming at bringing about and facilitating a conceptual change in order to achieve scientific conceptual understanding. Given that the sample group of the study will be teachers in the future, educational approaches and materials which would provide conceptual understanding are increasingly becoming more important in undergraduate level education. As for the subject of sound, there is the need for further studies on conceptions for every educational level, particularly for primary and secondary education.

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