PORTUGUESE SCHOOL TEXTBOOKS' ILLUSTRATIONS AND STUDENTS' ALTERNATIVE CONCEPTIONS ON SOUND

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ABSTRACT

School textbooks are an outstanding resource in school physics. The illustrations included in the textbooks may play an important role in the learning process as they can facilitate the understanding of the scientific content.
Acoustics is both a part of the 8th grade physical science syllabus and a physics topic that includes abstract concepts, such as the concept of wave. Besides, students hold several alternative conceptions on sound. Therefore, textbooks' illustrations should be carefully chosen in order to facilitate students' learning and to prevent their alternative conceptions from being reinforced and/or induced by them.
Thus, this study aims at analysing the illustrations included in Portuguese 8th grade school physics textbooks in order to find out whether or not they may promote the reconstruction of students' alternative conceptions on "Sound and Hearing".
The results of the study show that often textbooks' illustrations do not facilitate learning. In fact, some illustrations were found to be incomplete or even incorrect, others compare to alternative conceptions held by students and others include analogies that may lead to alternative conceptions.
Thus, science teacher education needs to prepare teachers to look critically at school textbooks so that they become aware of the powers and limitations of textbook's illustrations and find ways of overcoming their inconvenience.

1. INTRODUCTION

School textbooks are seen by the Portuguese educational system act [1] as an outstanding resource that deserves special attention. In fact, they influence teachers' practice [2, 3] and should be a valuable resource for students to study the content taught in school. When using a textbook, students have to read the text and to look at the pictures, and to make sense of both of them. This process of sense making is dependent on students' previous knowledge and experience in the topic and in other related areas.

While the written text is usually given much attention, illustrations are seen as motivating devices and therefore little care is put on them [4]. Nevertheless, the ministry of education includes an item on illustrations in the list of criteria to be used by teachers when choosing a school textbook among those available in the market. The item reads as follows: "The different types of illustrations are correct, pertinent and adequately related to the text." [5]. According to this document, illustrations can be of different types, namely photographs, drawings, maps, graphs and schemes.

Whatever the type, illustrations can play different roles in education. Motivation is one of them. However, the major role of illustrations arises from their capacity to transmit information about reality that is impossible or hard to be directly observed [4]. On the other hand, illustrations have no efficacy on their own. Their efficacy depends on their conditions of use that is, on the context activities they are used in [6]. It is through the activities that the learner takes over the illustration and learns from it. Nonetheless, the quality of the illustrations can facilitate learning or rather make it hard to happen.

In fact, there is some evidence [4, 7] that textbooks' illustrations may reinforce or induce alternative conceptions in students' mind. Sound is one of the physics themes that include concepts that cannot be visualised by the students (e.g.: wave). This may be the reason why research studies carried out with the aim of identifying students' alternative conceptions on Sound and Hearing have shown that Portuguese students [8, 9, 10] as well as students of other nationalities [11, 12, 13, 14] hold several alternative conceptions on the theme. From these studies it follows that some of the most prevailing conceptions are:

- Sound is a sort of wind;
- Sound is a material entity made of particles or sound waves;
- Sound is transmitted in a certain direction by collisions between particles;
- Sound spreads out through the empty spaces of the medium;
- Sound cannot go through the surface of separation of two different media;
- Echo is the result of a collision of sound with an obstacle.

These conceptions are resistant to traditional teaching and some of them also persist after constructivist teaching,

specially designed to promote their change [8].

2. OBJECTIVE OF THE STUDY

The objective of this study is to analyse eight-grade school physics textbooks in order to find out whether illustrations included in the teaching unit "Sound and Hearing" may promote the reconstruction of students' alternative conceptions or rather they may induce or even reinforce alternative conceptions in students' mind.

3. METHODOLOGY

It is our belief that the analysis of textbooks in use in schools increases the importance of this study. Thus, it was decided to analyse the last edition of the textbooks available in the market. In Portuguese schools, the last 8th grade physics textbooks selection was done for the academic year 1999/2000. Therefore, for the majority of the textbooks, the 1999 edition is the latest edition and it was the one analysed. In the remaining cases, the 1996 edition was analysed. As far as it is known, the 14 textbooks analysed (appendix 1) are those available in the market for the 8th grade.

Some of the topics included in the teaching unit "Sound and Hearing" were selected for the analysis. These topics are the following: propagation of sound and acoustic phenomena (reflection and echo, and refraction).

For each topic, illustrations that have a complementary role to the understanding of the written presentation of concepts and phenomena were analysed. This analysis aims at finding out whether those illustrations may facilitate learning or whether they may rather induce or even reinforce alternative conceptions in students' minds.

Illustrations were classified into three main independent categories, as follows: F – facilitate learning, if they seem correct from a scientific point of view and enough information is given; R – induce or reinforce alternative conceptions, if they are consistent with alternative conceptions held by the students and/or if they omit information needed for its correct interpretation; N – neutral, if it cannot be anticipated that they may either promote a cognitive conflict or reinforce an alternative conception. Some illustrations that cannot be understood even with the help of the written text were classified as "other" (O).

4. RESULTS

4.1. Propagation of Sound

Table 1 shows the results from the categorisation of the 41 illustrations related to the propagation of sound that were analysed. The number of illustrations analysed per textbook ranges from one (B, C) to six (H). Four illustrations may facilitate learning and three are neutral. The large majority of the illustrations may reinforce students' alternative conceptions on sound.

The illustrations were dived into three groups, according to the objective that can be attained with them. One group contains illustrations of a perturbation at a given moment that aim at helping students to imagine what sound is. The second group focuses on illustrations that show the propagation of a perturbation without making any reference to the mechanism of propagation. Finally, the third group includes illustrations concentrating on the mechanism of the propagation of sound.

Table 1: Categorisation of the illustrations on propagation of sound

Objective	Illustration	f	Textbooks													
			A	B	C	D	E	F	G	H	I	J	K	L	M	N
Visualisation of perturbation(s)	circles in water	4					R				R	R			R	
	circles in the air	8		R		R R		R	R	R				R		R
	strings	1									R					
	slinky tran.	3	R					R			R					
	springs lon.	3	N					N		N						
	domino	1					R									
	continuous	2						R	R							
	corpuscular	4			F							F	F R			
	mixed	2				R					R					
Visual. Propag. perturb.	slinky spring - trans.	1								R						
Mechanism of propagation of a sound wave	corpuscular	1											F			
	continuous	1												R		
	mixed	5	R				R							R	R	R
	slinky springs	1								R						
Graph of a sound wave	oscilloscope	2							R	R						
	scheme	2						R		R						

Analogies with a perturbation in water, in the air, in a string, in a slinky spring or in a domino are utilised in order to give an idea about what sound is. There is only one illustration visualising the propagation of sound by analogy with the propagation of a pulse in a slinky spring (H). None of these analogy based illustrations were considered as facilitators of learning and only three seem to be neutral (A, F, H). The water and air analogies turn out into illustrations that include circles/curves to show the perturbation of the medium in a given instant. Those circles/curves can lead students to materialise the sound waves or to reinforce the alternative conception "sound is a material entity".

The visualisation of a perturbation is also illustrated at the continuous level, the corpuscular level or by a mixture of one of these levels and a graphical representation of a wave. A well-drawn corpuscular illustration (C, J, K) is the only one that can give an adequate idea about what sound is and thus can facilitate learning on sound. The continuous level illustrations are based on the existence of zones of high and low pressure or high and low concentration of air. As students believe that pressure is due to wind [15], this type of representation may reinforce the idea that "sound is a sort of wind". The mixed illustrations put side by side the corpuscular or the continuous instantaneous representations of a perturbation

and a graphical representation of a wave (Fig.1). As the graph usually appears without any verbal explanation, its association with one of the other illustrations may induce the idea that sound, particles or material blocks can move along a sinusoid.

The illustration based on the domino effect (Fig.2) may reinforce the alternative conception "sound is transmitted in a certain direction by collisions between particles". The first part of this conception may also be reinforced by the illustrations showing a pulse in a slinky spring (H) and in a string, as the pulse is able to move in one only direction.

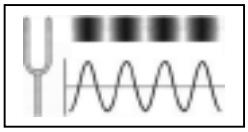

Fig. 1: In textbook A, p. 97

Fig. 2: In textbook E, p. 192

As far as the propagation of a perturbation is concerned, the only illustration found (H) shows a pulse in a slinky spring, at different moments. However, it shows a transversal pulse which has no relationship with the propagation of sound but can reinforce the idea of propagation along a sinusoidal curve.

As far as the propagation of sound is concerned, it is illustrated at a corpuscular level or at a macroscopic continuous level, by using light and dark areas that try to illustrate variations in pressure (Fig.3). There are also some mixed illustrations (as defined above) and some analogy based illustrations, namely with the propagation of a perturbation in a slinky spring. The fact that these representations include different instants in time does not abolish the inconveniences discussed above with regard to some of them. Besides, the illustration including a slinky spring (H) could be helpful if there was not a coloured spire drawn in different places at different moments, leading the textbook user to both think that the spires can have a translation movement and apply this idea to the case of sound propagation.

The graphic representation of a sound wave is included in three textbooks, being shown on the screen of an oscilloscope (G, H), drawn in a graph (F) or represented as a set of circles displayed according to a sinusoid (H) (Fig.4). The former representation can induce the idea that sound can be seen and they all may reinforce the idea of sound as a material entity that propagates along a sinusoid.

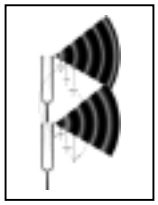

Fig. 3: Textbook L, p. 79

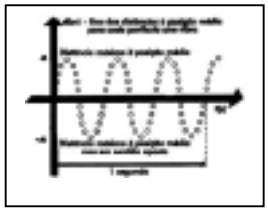

Fig. 4: Textbook H, p. 169

The graphical representation included in textbook H shows the displacement of the particles from their equilibrium position (Fig.4). This representation can induce or reinforce the idea that particles tend to be "glancing" in such a manner as to give rise to the correct changes in direction to form a sinusoidal shaped collision–wave [11].

4.2. Acoustic Phenomena

Three acoustic phenomena will be considered for the analysis. They are reflection and echo, and refraction.

4.2.1. *Sound Reflection and Echo*

The illustrations on reflection and echo (Table 2) try to show reflection at a qualitative level (Fig.5) or at a quantitative level, showing the laws of reflection (Fig.6).

Table 2: Categorisation of the illustrations on sound reflection and echo

Object-ive	Illustration	f	Textbooks													
			A	B	C	D	E	F	G	H	I	J	K	L	M	N
Qualit-ative visual-isation of reflection	circles in the air	7	R	R	R					R			R		R	R
	circles in water	4			R			R						R		R
	direction of the waves	5		N		R			R			F			F	
	mixed	3				D		R			R					
Laws of reflection	angles of the waves	2					F					F				
	circles in the air + angles	1														R
	mixed	1						R								

The use of circles/curves (often without captions) to represent sound (sometimes in real pictures, as shown in Fig.5) may once again reinforce the idea of sound waves as material entities. Besides, it can induce a mechanist idea of reflection as sound can be seen as something that collides with an obstacle and is thrown back.

Fig. 5: Textbook A, p. 104

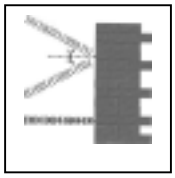

Fig. 6: Textbook N, p. 139

The illustration shown in Fig.7 is similar to the one given in Fig.6 but the captions together with the arrows may lead the reader to think that sound (som) is what is sent towards the obstacle (obstáculo) and echo (eco) is what is thrown back. Therefore, this illustration can reinforce the idea that "echo is the result of a collision of sound with an obstacle".

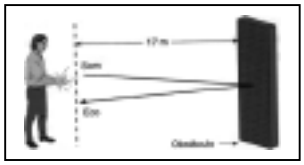

Fig. 7: Textbook G, p. 165

4.2.2.Sound Refraction

Table 3 shows the results of the categorisation of the 12 illustrations related to the refraction of sound. They aim at showing refraction at a qualitative level that is, without mentioning angles. On the other hand, illustrations may try to show refraction in two media (Fig.8) or in a medium, due to the existence of zones of different temperatures or pressures (Fig.9).

Table 3: Categorisation of the illustrations on sound refraction

Object-ive	Illustration	f	Textbooks													
			A	B	C	D	E	F	G	H	I	J	K	L	M	N
Qualit-ative visual-isation	two media	6			O			O				R		O	R	R
	one medium	6	R	O			R	R		O			R			

It should be pointed out that several illustrations related to this phenomenon were classified as "Other", as it was very hard for us to guess their meanings and we think it would be impossible for the students to make sense of them (Fig.9).

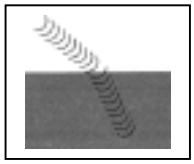

Fig. 8: Textbook N, p. 142

Fig. 9: Textbook B, p. 231

Usually, straight lines, curves, and coloured areas are used to show the sound pathways. This way of illustrating refraction may also have undesirable consequences for students' learning for the reasons mentioned above. Besides, in some cases, illustrations are so schematic and lack so much verbal information/captions that it is a hard job to make sense of them (Fig.9).

5. CONCLUSIONS AND IMPLICATIONS

The results of this study lead us to conclude that the 8th grade physics textbooks illustrations intended to facilitate the comprehension of the topics "propagation of sound" and "acoustic phenomena" seldom have the potentiality of succeeding in doing so. Moreover, they can reinforce or even induce alternative conceptions that prevail among students of this grade level.

As it was referred to above, the activities done with the illustrations are far more important than the illustrations themselves. This means that a good illustration may be useful or not, depending on what is done with it. However, a non-understandable illustration can hardly have any educational value. On the other hand, the incorrect illustrations can be discussed with students and corrected in order to become useful. Nevertheless, one cannot forget that a visual image is much easier to retain than a verbal explanation. This means that students can easily forget the explanation and keep the incorrect illustration, especially when the latter is in agreement with their own ideas.

Textbooks are human enterprises and should not be expected to be perfect materials [16]. However, more care should be put on the illustrations they include so that textbooks become more useful teaching and learning resources.

Besides, teachers should be made aware of the role of illustrations as well as about their powers and limitations not only in order to select the most appropriate textbooks but also in order to help students to cope with illustrations that have severe problems.

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APPENDIX 1: List of Textbooks Analysed

A-Figueiredo, T. & Mateus, V. (1999). *Eureka - Ciências Físico-químicas-8º ano*. (Lisboa, Texto Editora)

B-Morgado, J., Morgado, G. & Canelas, E. (1999). *Encontro com a Física - Ciências Físico-químicas-8º ano.* (Lisboa, Plátano Editora)

C-Fernandes, M.B., Graça, O. C. & Santos, R.M. (1999). *Física - Ciências Físico-químicas-8º ano.* (Lisboa, Lisboa Editora)

D-Cavaleiro, M. & Beleza, M. (1999). *No Mundo da Física -3º ciclo do Ensino Básico -8º ano.* (Porto, Edições Asa)

E-Morais, A.M., Ribeiro, L. & Silvia, I. (1999). *Química e Física - 8º ano*. (Porto, Porto Editora)

F-Gonçalves, C., Souto, A. & Pereira, A. (1999). *CFQ - Física -8ºano.* (Porto, Porto Editora)

G-Dias, F., Rodrigues, M.M. (1999). *Física na Nossa Vida - Físico-químicas-8º ano.* (Porto, Porto Editora)

H-Mendonça, L. & Ramalho, M. (1999). *No Mundo em Transformação - Física - 8º ano.* (Lisboa, Texto Editora)

I-Maciel, M. & Miranda, A. (1999). *Eu e a Física 8º.* (Porto, Porto Ed.)

J-Viegas, C. (1996). *Física - Físico-química - 8º ano.* (Lisboa, OLivro)

K-Martins, A. (1996). *Física em Temas - 8º ano.* (Porto, Porto Editora)

L-Fiolhais, et al. (1999). *Física - 8º ano*. (Lisboa, Didáctica Editora)

M-Martins, M. (1996). *Nova Física -8.* (Lisboa, Areal Editores)

N-Ferrão, M. & Sílvia, M. (1996). *Físico-químicas-8.*(Lisboa, Constância)

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