356 - Science Textbooks as Questioning and Problem-Based Teaching and Learning Promoters: Change or Continuity?

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Abstract: High-level questioning is the starting stone of Problem-Based Learning (PBL). This student centred teaching approach is especially appropriate for complex themes, as these are more likely to include real life problems. Sustainability on Earth is the Portuguese National Curriculum theme that better fits this criterion. This paper concentrates on the way Portuguese science textbooks focusing on Sustainability on Earth deal with questioning, in order to find out whether they may foster continuity with regard to teacher-centred teaching approaches or whether they rather seem to promote change towards innovative student-centred problem-based science learning. Three Physical and three Natural Sciences textbooks were content analysed with regard to the way they deal with questions and the cognitive level of the questions they include. Results indicate that textbooks: include a considerable amount of questions; use questions in different ways and for diverse purposes; tend to prefer low-level cognitive questions; hardly include problem-oriented questions.

Keywords: Science textbooks, Problem-Based Learning, questioning, Sustainability on Earth

INTRODUCTION

The Portuguese Educational System Law (law number 49/2005, 30 August, 2005) acknowledges science textbooks as an outstanding educational resource. However, research has shown that textbooks are conservative with regard to the way they develop curriculum themes, as they hardly integrate knowledge from educational research and acknowledge curriculum prescribed methodological innovations (Moreira, 2003). Besides, research also suggests that teachers teaching practices are heavily dependent on textbook for what they decide to teach and the way they decide to teach it in the classroom. Thus, textbooks act as if they were the official curriculum that many teachers tend to ignore. Hence, if textbooks are conservative, then they may contribute to teachers' conservative teaching practice.

Research (Figueiroa, 2003) has shown that textbook authors refrain from innovating in their textbooks because they feel afraid that teachers do not feel comfortable with innovative textbooks and may not choose them to be assigned in their school. In-service teacher education would help teachers to understand the aim of educational innovation and would make them prone to accept innovative textbooks. However, availability of innovative textbooks may also make some teacher feel the need of engaging in teacher development courses in order to be able to do the most with innovative textbooks. Thus, writing innovative textbooks would be one of the ways of "breaking the continuity chain" and promoting innovative teaching. On the other hand, success may be greater if teachers that attend in-service courses, can find textbook that are consistent with the perspectives conveyed into the course and that facilitate their task of putting into practice the new ideas or methodologies they learned.

This would be especially important when educational innovations that require major changes in teachers' and students' roles are at stake. Problem-based learning (PBL) is a methodological approach that requires major changes in teachers' and students' roles (Azer, 2008; Leite & Esteves, 2006; Savin-Baden & Major, 2004). In PBL environments, instead of teaching I the usual sense, teachers need to organize learning settings for students to learn on their own (Lambros, 2004). Students, by their turn, need to become active learners, as they will not be taught but rather learn by solving problems (Hmelo-Silver, 2004), that should be as real as possible (Lambros, 2004; Hmelo-Silver, 2004). A consequence of this is that teachers may feel uncomfortable and unsecure towards PBL (Dahlgren, Castensson & Dahlgren, 1998; Gandra, 2001). Besides, teachers may not have a pool of problems or scenarios from were to choose the most appropriate ones to use as starting points in PBL oriented teaching sequences. In this case, high-level textbook questions would become useful teaching aids, as they could facilitate teachers' teaching practices change towards PBL oriented ones.

Following authors like Hmelo-Silver (2004), Lambros (2004) and Azer (2008), this paper assumes that high-

level questioning is the starting stone of PBL. By high level questioning it is meant a process in which someone questions formulates questions that require high-order thinking to be answered. Besides, a question may be conceptualized as an issue put forwards for discussion in such a way that it demands an answer (Ferreira, 2010), even though it does not end with a question mark. Hence, questions compare to problems, as both include an obstacle that needs to be overcome by the respondent or problem solver.

Questioning has concentrated several researchers' attention and being studied within diverse educational contexts and from several perspectives (Wragg & Brown, 2001). Initially, those studies were quantitative in nature and concentrated on the amount and rate of questions formulated by the teacher. Latter on, researchers concentrated on the classroom interaction and on subjects questioning abilities, including issues like types of questions formulated by students and teachers in diverse contexts. Researchers in this area have developed several taxonomies of questions that emphasise differently the cognitive, the procedural and the values components. Dalghren & Öberg (2001) defined a taxonomy of students' formulated questions that combines al these dimensions, that Dourado & Leite (2010) found useful to analyse textbook questioning level. It includes five categories, as follows: Encyclopaedic Questions, demand an unambiguous and non complex answer (e.g., What is the greenhouse effect?); Meaning-Oriented Questions, oriented towards finding a phenomenological meaning of certain terms or concepts (e.g., How are images formed in our eyes?); Relational Questions, focus on the relationship between aspects/features (e.g., How do technological societies influence the ozone layer?); Value-Orientated Questions, demand for a judgment based on some criteria (e.g., Bearing in mind that Portugal has to reach an energy goal settled within the scope of the Kyoto protocol, should this dam be built up?); Solution-Oriented Questions, focus on looking for solution(s) for a (social, environmental, health, economic, etc) problem (e.g., What can be done to prevent the energy crises?).

This paper also acknowledges that PBL is a student centred teaching approach that is especially appropriate for dealing with complex themes that should be tackled from several perspectives in order to be fully understood. Thus, complex themes are more likely to include real life problems, which are required for PBL approaches. As Pring (quoted by Santomé, 1998) would put it, when the problem becomes the focus of the educational action, it determines what competences are required and eventually will need to be developed. Thus, by putting the problem at the centre, the boundaries between school subjects will vanish and cross-disciplinary approaches will emerge.

Among the four Portuguese National Curriculum themes, Sustainability on Earth is the curriculum theme that better fits this criterion. It is supposed to be taught is in the Physical Sciences as well as in the Natural Sciences junior high school science subjects. This fact together with the cross-disciplinary nature of the theme leads to anticipate that it could be approached from a PBL perspective that could develop in a global manner the competences prescribed by the national curriculum (DEB, 2001) for the two subjects together. The ways textbooks develop the theme as well as the way they deal with questioning may be promote or rather impair teachers from doing so.

In this context, this paper concentrates on the way Portuguese science textbooks focusing on Sustainability on Earth deal with questioning, in order to find out whether they may foster continuity with regard to teacher-centred teaching approaches or whether they rather seem to promote change towards innovative student-centred problem-based science learning.

METHODOLOGY

Three Physical and three Natural Sciences textbooks dealing with the theme Sustainability on Earth were selected for the purpose of this study. These Portuguese textbooks were randomly chosen on the basis of the publisher, so that three different textbook publishers (and a textbook per subject and publisher) were taken. In order to attain the objective of the study, the textbooks were content analysed with regard to the way they deal with questions and the cognitive level of the questions they include. All questions were analysed except questions within an activity and end of teaching unit assessment questions. The reason for excluding within an activity questions was that the way the activity is introduced is far more important from a PBL point of view than the way the activity is prescribed. With regard to the exclusion of final assessment questions, it can be argued that although they are relevant from a self-evaluation perspective and can be used for enhancing learning, they nevertheless are not relevant from a PBL perspective, as they come after teaching and learning.

It should be pointed out that one of the textbooks (PS 3) is not consistent with the curriculum with regard to the teaching units it acknowledges. However, in order to get conditions to compare teaching units, the way it develops the theme enabled us to join two of its units and to divide a third one (into other two) and to get

teaching units similar to those suggested by the National curriculum and used by the remaining textbooks in the sample.
Questions were analysed through a checklist that had in part been used in former studies (Dourado & Leite, 2010; Vasconcelos *et al*, in press). In order to increase reliability of the results, the analysis was done by one of the authors and repeated by another author. The three authors discussed discrepancies in the classifications in order to reach a consensus with regard to the final classification to be adopted. In order to compare textbooks, percentage of type of questions per textbook was calculated. Examples of questions classified in the main categories will be given in the next section.

Presentation and discussions of the results
As shown by table 1, textbooks are quite different with regard to number of questions they include, being Physical Sciences textbooks (PS) those that include larger numbers of questions.

Table 1: Number of questions per textbook and subject (f)

Textbook	**Number of questions**	**Number of questions per subject**
NS 1	160	232
NS 2	46	
NS 3	26	
PS 1	286	924
PS 2	258	
PS 3	380	

This result may be due to the fact that traditionally PS textbooks include lots of exercises and a few problems fro students to solve or to see how they can be solved. This is not so usual in the Natural Sciences textbooks (NS), which include very different numbers of questions.
Textbooks selected for this study include questions in different places, ranging from the opening of the theme (NS 1, PS 1 and PS 2) end of unit complimentary questions (PS 2). Besides, as shown in table 2, NS and PS textbooks are quite different with regard to the places they include questions. In fact, while PS textbooks tend to concentrate questions throughout the text, after the presentation of the content, two NS textbooks tend concentrate them on the title of the activities and the third NS textbooks does it in the margin of the page, aside from the main text.

Table 2: Placement of the questions in the textbooks (%)

Localization of the questions		**NS 1** (n_1=160)	**NS 2** (n_2=46)	**NS 3** (n_3=26)	**PS 1** (n_1=286)	**PS 2** (n_2=258)	**PS 3** (n_3=380)
Opening of the theme		1,9	0,0	0,0	0,7	0,3	0,0
Opening of Units		0,0	30,4	0,0	0,0	0,0	18,7
Title of sub-units		0,0	0,0	0,0	11,5	0,0	0,0
Title of sections		0,0	0,0	0,0	0,0	0,0	0,0
Title of sub-sections		1,9	0,0	0,0	0,0	0,3	26,6
Throughout a sub-unit or section text	Integrated into the content being presented	6,3	0,0	26,9	11,2	12,4	3,4
	After the content presentation	0,0	0,0	0,0	50,7	77,1	42,4
	Resolved questions	0,0	0,0	0,0	0,0	2,7	0,0
	Aside content presentation	86,9	0,0	0,0	24,1	0,0	0,0
Associated to learning activities	Activities title	2,5	69,6	73,1	1,7	0,3	5,5
	Activities statement	0,6	0,0	0,0	0,0	0,3	3,4
End of the unit complimentary questions		0,0	0,0	0,0	0,0	6,6	0,0

Including questions after content presentation is a traditional way of using questions, which is opposite to the problem based learning way of using questions. On the other hand, three textbooks include questions in the

opening page of the theme. These questions are quite important as they can be used as starting points for a PBL approach to the teaching of the theme. Also, as these questions are usually broad questions, they cannot only motivate students to learn but also promote an integrated learning of the content. However, it should be noticed that these questions are the ones that are proposed by the National Curriculum and are not a textbook authors initiative. Figure 1 shows an example of an opening page of the theme, that repeats the following questions included in the national curriculum: Why are ecosystems in dynamic equilibrium? Haw can science and technology take the most from the use of natural resources? How has Humanity contributed to global change?

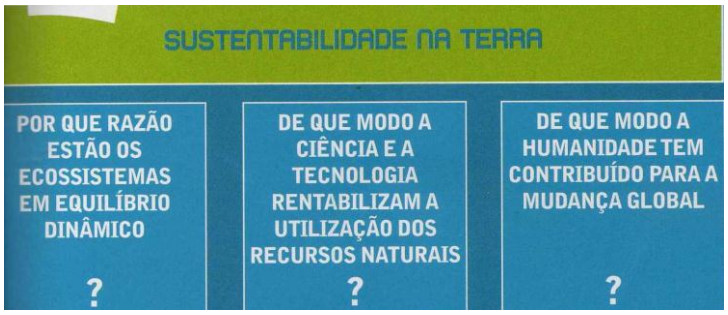


Figure 1: Questions in the opening page of a teaching unit (NS 1, p. 7)

On the other hand, it should be emphasized that NS 2 and PS 3 include considerable percentages of questions in the opening pages of the teaching units. Figure 2 shows an example of the questions presented in the opening page of a teaching unit of textbooks PS 1.

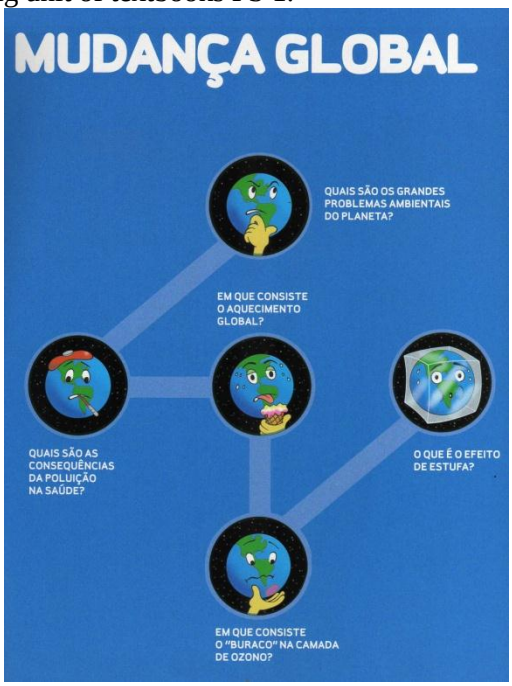
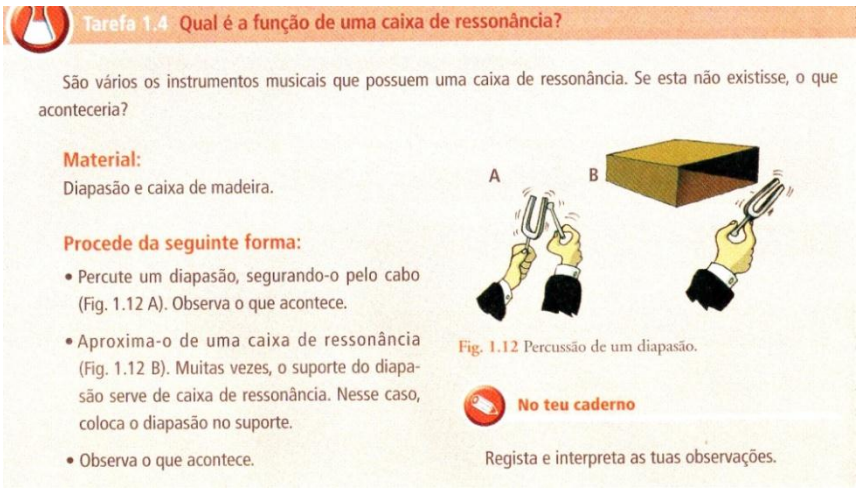


Figure 2: list of questions in the opening page of the teaching unit (PS 1, p. 156)

Questions in this category are of the initiative of the textbook authors and can reveal some awareness of the value of PBL. In fact, teachers can use these questions as starting points to learning. They are qualitative, conceptual questions appropriate for students to investigate about issues: What are the main environment problems of the Planet? What is global warming about? (free translations of the two first/top questions in figure 2).

Some textbooks use questions as titles for activities (figure 3). This way of using questions makes it clear for the students what they are looking for when solving the activity. In figure 3, what is the role of the resonance box? It also makes students feel the need for getting an answer, by solving a problem that is, by performing the activity. Therefore, it is consistent with the PBL idea of starting with a problem.


Tarefa 1.4 Qual é a função de uma caixa de ressonância?

São vários os instrumentos musicais que possuem uma caixa de ressonância. Se esta não existisse, o que aconteceria?

Material:
Diapasão e caixa de madeira.

Procede da seguinte forma:
- Percute um diapasão, segurando-o pelo cabo (Fig. 1.12 A). Observa o que acontece.
- Aproxima-o de uma caixa de ressonância (Fig. 1.12 B). Muitas vezes, o suporte do diapasão serve de caixa de ressonância. Nesse caso, coloca o diapasão no suporte.
- Observa o que acontece.

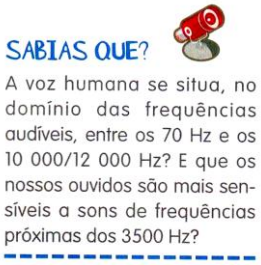
Fig. 1.12 Percussão de um diapasão.

No teu caderno

Regista e interpreta as tuas observações.

Figure 3: Question in the title of the activity (PS 3, p. 20)

Textbook PS1 is includes several questions throughout the text, but aside from the main text, that seem to aim at raising students' curiosity (Sabias que? or Did you know that?). This type of questions usually inquires students about whether they knew about or had heard about something. Example given in figure 4 asks students about whether they knew about the frequency of human voice and the frequencies that human hears are most sensitive to. In fact, these questions concentrate on particular aspects that are not that important from the school subject point of view but that can be interesting or even relevant from a personal point of view. Nevertheless, these questions do not require high-level reasoning and therefore they are not relevant from a PBL point of view.


SABIAS QUE?

A voz humana se situa, no domínio das frequências audíveis, entre os 70 Hz e os 10 000/12 000 Hz? E que os nossos ouvidos são mais sensíveis a sons de frequências próximas dos 3500 Hz?

Figure 4: Question for raising curiosity (PS1, p. 30)

The places where questions can be found in textbooks when they develop this curriculum theme (Sustainability on Earth) compares to those indentified for the theme Earth in Transformation (Vasconcelos et al, in press). Although textbooks used in the two studies do not belong exactly to the same collections/editors and, therefore, a textbook based theme to theme comparison cannot be done, it can nevertheless be stated that, in the overall, textbook follow similar patterns when approaching the two curriculum themes.

Comparing data given in tables 2 and 3 it can be stated that, in most cases, the place of the questions is directly related to their functions in the textbook.

Table 3: Role of the questions (%)

Role of the question	**NS1** (n_1=160)	**NS 2** (n_2=46)	**NS 3** (n_3=26)	**PS 1** (n_1=286)	**PS 2** (n_2=258)	**PS 3** (n_3=380)
Present expected learning results	1,9	30,4	0,0	12,2	0,4	18,7
Present the text to be developed	2,5	0,0	26,9	1,0	1,9	26,6
Link parts of a text on a given issue	5,6	0,0	0,0	10,1	10,9	3,4
Present compulsory learning activities	3,1	69,6	73,1	1,7	7,0	8,9
State knowledge application activities	0,0	0,0	0,0	50,7	77,1	42,4
Try to keep readers' attention	86,9	0,0	0,0	24,1	0,0	0,0
Show how to solve a problem/exercise	0,0	0,0	0,0	0,0	2,7	0,0

As they are not supposed to be answered at the stage they are introduced, their aim cannot be associated to diagnosing students' ideas on the issues they focus on. Thus, questions in the opening of theme or unit and title of section or sub-section can be better interpreted as presenting learning results as they give students an idea of what they are supposed to learn about. Figure 5 shows one of those questions (How are living organisms organized in the biosphere?) that is associated to a conceptual scheme that gives an overall idea of what is going to be learnt.

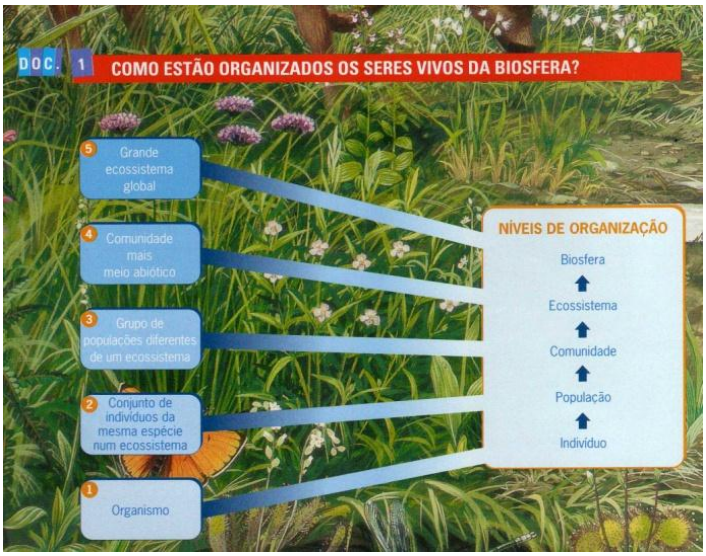


Figure 5: Question aiming at presenting learning results (NS 2, p. 12)

Some textbooks use questions throughout the text to link parts of the text or to introduce knowledge application activities. In the former case, the questions help to keep the reader's attention and promote understanding because even they may not be answered, they interrogate the reader about what he/she is reading. Figure 6 shows one of those questions (free translation: But, science and technology innovations are good or bad from the humanity?).

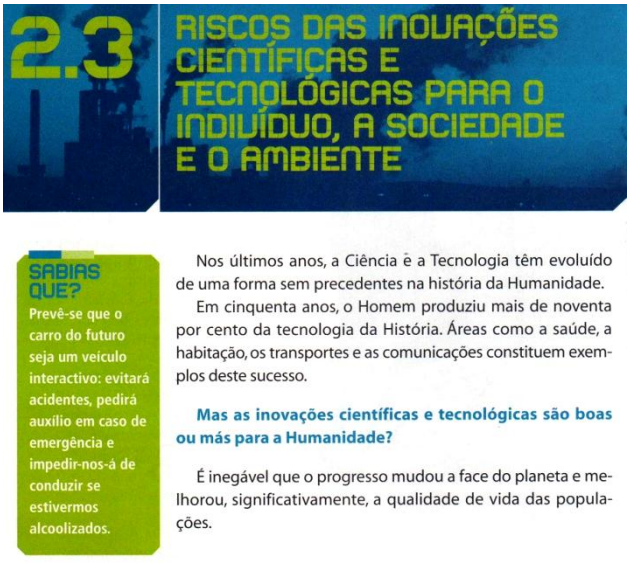
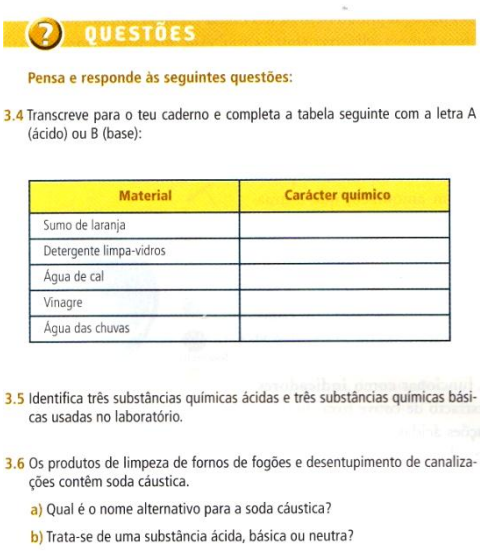


Figure 6: question that link parts of a text (NS 1, p. 202)

Application questions are relevant to help students to get feedback on their own learning but as they come after learning, they are not useful from a PBL perspective. Figure 7 gives an example of questions used for this purpose. These questions concentrate on the chemical character of some substances everyday (e.g., orange juice, vinegar or rainwater) or lab substances.



QUESTÕES

Pensa e responde às seguintes questões:

3.4 Transcreve para o teu caderno e completa a tabela seguinte com a letra A (ácido) ou B (base):

Material	Carácter químico
Sumo de laranja	
Detergente limpa-vidros	
Água de cal	
Vinagre	
Água das chuvas	

3.5 Identifica três substâncias químicas ácidas e três substâncias químicas básicas usadas no laboratório.

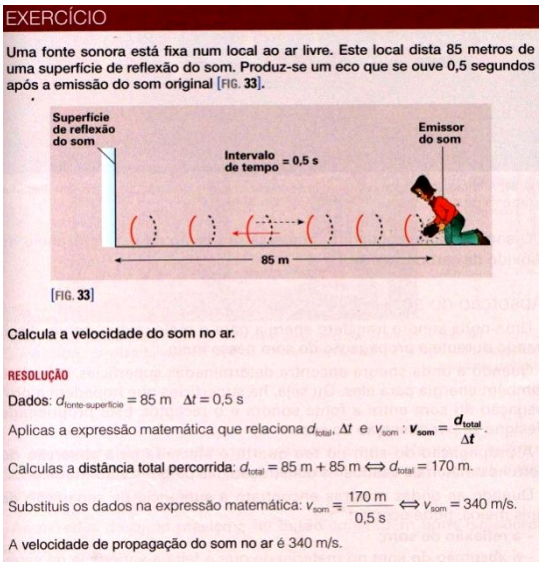
3.6 Os produtos de limpeza de fornos de fogões e desentupimento de canalizações contêm soda cáustica.

a) Qual é o nome alternativo para a soda cáustica?

b) Trata-se de uma substância ácida, básica ou neutra?

Figure 7: Knowledge application questions (PS 3, p. 121)

Some textbooks also include questions to show students how to solve problems/exercises. Figure 8 shows a question that requires students to calculate on sound speed. This type of questions aims at developing students' exercise solving skills. Although some of these skills may be relevant for problem solving, these questions are not relevant from a PBL point of view, as they require previous knowledge that is available only after teaching.



EXERCÍCIO

Uma fonte sonora está fixa num local ao ar livre. Este local dista 85 metros de uma superfície de reflexão do som. Produz-se um eco que se ouve 0,5 segundos após a emissão do som original [FIG. 33].

Superfície de reflexão do som

Intervalo de tempo = 0,5 s

Emissor do som

85 m

[FIG. 33]

Calcula a velocidade do som no ar.

RESOLUÇÃO

Dados: $d_{fonte\text{-}superfície} = 85$ m $\quad \Delta t = 0{,}5$ s

Aplicas a expressão matemática que relaciona d_{total}, Δt e v_{som}: $v_{som} = \frac{d_{total}}{\Delta t}$.

Calculas a **distância total percorrida**: $d_{total} = 85 \text{ m} + 85 \text{ m} \Leftrightarrow d_{total} = 170$ m.

Substituis os dados na expressão matemática: $v_{som} = \frac{170 \text{ m}}{0{,}5 \text{ s}} \Leftrightarrow v_{som} = 340$ m/s.

A **velocidade de propagação do som no ar** é 340 m/s.

Figure 8: Question used to show to solve a problem/exercise (PS 2, p. 31)

With the exception of the NS3 textbook, most of the questions are encyclopaedic or meaning-oriented questions (table 4). The former requires rote learning, has no relationship to problems and is not relevant from a PBL perspective. Meaning-oriented questions require understanding and therefore they can be useful within PBL approaches even though they do not require very high reasoning levels. The other three types of questions are much more interesting as they require high level reasoning, namely the establishment of relationships, the making of judgements and the drawing of solutions for problems. Examples of the diverse types of questions were given in the introduction section of this paper. It should be noticed that a few questions were not classified into the five main categories as they were not well formulated and could not be understood well enough to be classified into those categories.

Table 4: Cognitive level of the questions (%)

Category	**NS 1** (n_1=160)	**NS 2** (n_2=46)	**NS 3** (n_3=26)	**PS 1** (n_1=286)	**PS 2** (n_2=258)	**PS 3** (n_3=380)
Encyclopaedic	90,0	13,0	19,2	60,8	58,1	47,6
Meaning-oriented	8,1	67,4	42,3	37,4	41,5	49,5
Relational	1,3	15,2	3,8	1,7	0,0	2,4
Value-oriented	0,6	0,0	0,0	0,0	0,0	0,0
Solution-oriented	0,0	2,2	34,6	0,0	0,0	0,3
Other	0,0	2,2	0,0	0,0	0,4	0,3

CONCLUSION

Textbooks differ with regard to the amount and the way they use questions, being NS textbooks quite similar among them but a bit different from the PS ones. PS textbooks tend to emphasise application questions while NS textbooks tend to emphasise question oriented activities. On the other hand, with the exception of the NS 3 textbook, most of the questions included in the textbooks analysed are encyclopaedic or meaning-oriented questions. Thus, textbooks questioning might not be too much helpful if a PBL approach to Sustainability on Earth is to be put into practice. Textbook authors seldom suggest their own questions as starting points to content development. Taken together, these results indicate that teachers need to find out problems or to prepare scenarios if they want to apply this innovative student-centred teaching approach to the content theme that is at stake. In addition, as the Portuguese curriculum is not a Problem-Based Curriculum, then teacher education is needed in order to help teachers to integrate PBL in a competence based curriculum without failing the development of students' prescribed competences.

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ANNEXE: **Textbooks analysed**

NS 1 – Antunes, C. *et. al* (2010). *Novo Descobrir a Terra*. Maia: Areal Editores

NS 2 – Silva, A. *et al.* (2010). *Planeta Vivo, Sustentabilidade na Terra*. Porto: Porto Editora

NS 3 – Domingues, H. & Batista, J. (2010). *Gaia, Sustentabilidade na Terra*. Lisboa: Lisboa Editora

PS 1 – Silva, J. *et al*. (2010). *(CFQ) 8 Sustentabilidade na Terra*. Maia: Areal Editores.

PS 2 – Rodrigues, M. & Dias, F. (2010). *Física e Química na nossa vida, Sustentabilidade na Terra*. Porto: Porto Editora.

PS 3 – Fiolhais, C. *et al.* (2007). *8 CFQ Sustentabilidade na Terra*. Lisboa: Texto Editora

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