SOCIOLOGICAL STUDIES OF THE CLASSROOM

Vertical discourses and science education

Analyzing conceptual demand of educational texts

Ana M. Morais
Isabel P. Neves
Institute of Education, University of Lisbon

Revised personal version of the article proposed for publication in:
British Journal of Sociology of Education, November 2012
British Journal of Sociology of Education homepage:
http://www.tandfonline.com/toc/rred20/current

Vertical discourses and science education
Analyzing conceptual demand of educational texts

Introduction

The idea that science education should take into account the very nature of the scientific knowledge and that should also promote the development of scientific literacy by *all* students is an idea supported by academics who work within theoretical frameworks based on epistemological and sociological perspectives. Science education is education of scientific knowledge and, following Bernstein's conceptualization (1999), scientific knowledge is a vertical discourse with a hierarchical structure. Again following Bernstein, the education of science may be considered a vertical discourse with a horizontal structure and as such distinct perspectives co-exist of what can be considered as efficient scientific teaching to *all* students.

The level of complexity of scientific knowledge in science educational texts may be seen in terms of the concept of conceptual demand. In the paper, conceptual demand is explored from both theoretical and empirical points of view. From a theoretical perspective, the paper discusses the sociological meaning of the concept of conceptual demand of science education by using Bernstein's theorizing (1999) about vertical discourses and structures of knowledge. Also from a theoretical perspective, the paper uses Bernstein's model of pedagogic discourse, to relate conceptual demand to *the what* and to *the how* of the teaching-learning process.

From an empirical perspective, the paper describes the external language of description that has been developed to analyse the conceptual demand at various levels of the educational system - curricula, textbooks, pedagogic practices. The paper also gives some results of studies which have investigated the level of conceptual demand of the pedagogic discourse that is present in monologic (curricula and textbooks) and dialogic (pedagogic practices) texts, that is the level at which the hierarchical structure of scientific knowledge is to be taught and learned. It also presents results of the relation between the level of conceptual demand of science texts and students' scientific learning.

While presenting results of studies about conceptual demand and its relation to students' scientific learning, the paper intends to discuss the idea that different levels of conceptual demand in science education may correspond to different levels of the vertical discourse that characterizes the transmission-acquisition of scientific knowledge. It also intends to discuss that the access of *all* students to the hierarchical structure that characterizes scientific knowledge presupposes a sociological and pedagogical positioning about the meaning of *science for all*.

Theoretical framework

Vertical discourses

In the most recent development of his theory, Bernstein (1999) focuses on the *forms* of the discourses, i.e. in the internal principles of their construction and in their social basis that are subject to pedagogic transformation.

Bernstein starts from the distinction between 'horizontal' and 'vertical' discourses and considers, as the criteria for their definition, the distinct 'forms of knowledge' which are realized in the two discourses. The *horizontal discourse* corresponds to a form of knowledge which is segmentally organized and differentiated. Usually understood as the everyday or common sense knowledge, it tends to be an oral, local, context dependent and specific, tacit and multi-layered discourse. The *vertical discourse*, referred as school or official knowledge, presents the form of a coherent, explicit, hierarchically organized structure (as in the case of natural sciences) or the form of a series of specialized languages with specialized modes of questioning and specialized criteria of production and circulation of texts (as in the case of the social sciences and humanities). In the context of formal education, the distinction between the horizontal and vertical discourses corresponds to the distinction that is usually made between non-academic and academic knowledge, between local and official knowledge, the two discourses being ideologically positioned and differently evaluated.

Given the distinct nature of the horizontal and vertical discourses, the form taken by pedagogy and, consequently, the mode of acquisition of those discourses, has distinct characteristics. In the case of the horizontal discourse, knowledge to be acquired is related not by the integration of their meanings through a given coordinating principle but through the functional relation of segments or contexts to the everyday life. This means that what it is acquired and the form how it is acquired in a segment or context may not have any relation with what is acquired or how is acquired in another segment or context. For example, to learn how to do one's shoes laces has no relation with to learn how to sit at the table properly. Furthermore, the pedagogy of the horizontal discourse may also vary according to the segments and, depending on social groups/classes, similar segments may differ in the modality of code which regulates acquisition. The emphasis of this segmented pedagogy of the horizontal discourse lies, in general, in the acquisition of a common competence and not in a graded performance.

The integration within the vertical discourse is not made at the level of the relation between segments/contexts but at the level of meanings. Consequently, the procedures of the vertical discourse are not horizontally inter-related by the contexts but hierarchically inter-related to other procedures. Given the fact that the vertical discourse does not consist of segments culturally specialized but of specialized symbolic structures of explicit knowledge, the official or institutional pedagogy of the vertical discourse is a process that takes place along the time. Whereas there is contextual specificity through 'segmentation' in the horizontal discourse, there is contextual specificity through 'recontextualization' in the vertical discourse.

Bernstein distinguishes two modalities of knowledge within the vertical discourse - *hierarchical structures* and *horizontal structures* of knowledge. The hierarchical structures of knowledge (as in the case of natural sciences) correspond to forms of knowledge that are characterized by integrating propositions and theories that operate at more and more abstract levels, so that as to explicate the uniformity underlying an extensive range of apparently distinct phenomena. The horizontal structures of knowledge (as in the case of social sciences and humanities) are characterized by a series of specialized languages with their specialized modes of questioning and with specialized criteria for the production and circulation of texts. Whereas in the hierarchical structures of knowledge there is an integration of language, in the horizontal structures of knowledge there is an accumulation of languages.

If we take Biology as an example of knowledge of a hierarchical structure (Morais & Neves, 2007), we can say that the theory of evolution or the cell theory contain principles which integrate and unify ideas related to a set of biological phenomena and that the development of these theories results from a broader and broader conceptualization of former theories about the same phenomena. The development of a conceptual language in Biology, as in any knowledge with a hierarchical structure, may imply the refutation of former propositions or incorporation of former propositions into more general propositions but, in any case, it corresponds to development that occurs according to a hierarchical structure. If we take Sociology as an example of knowledge of a horizontal structure, we can say that functionalism, pos-structuralism, pos-modernism, etc., correspond to distinct languages within that area of knowledge which are not transmutable, as each one of them starts from distinct and sometimes opposed assumptions. Thus, whereas the development of hierarchical structures of knowledge corresponds to the development of successfully more general and integrating theories, the development of the horizontal structures of knowledge corresponds to the introduction of a new language, with a new set of questions and relations, with an apparent new problematic and with a new set of theoreticians/speakers.

In the case of the horizontal structures of knowledge, there is also a difference between the knowledge which has an internal language of description with strong grammars (e.g. economics, mathematics, linguistics and parts of psychology) and the knowledge which has an internal language of description with weak grammars (e.g. sociology, social anthropology and cultural studies). The difference lies in the fact that the former possess an explicit conceptual syntax which has the potential of generating relatively precise empirical descriptions and/or the construction of formal models of empirical relations. Another aspect which distinguishes horizontal structures of knowledge is related to the number of internal languages that characterize these structures, being smaller in the case of the structures of knowledge of strong grammars.

Speaking about these distinctions, Bernstein intends to make evident the internal principles of the construction of distinct areas of academic knowledge which are the subject of pedagogic transformation. He also gives special attention to the problems of acquisition of different forms of knowledge. He says that, within the hierarchical structures of knowledge, the acquirer is not concerned with the problem of knowing if s/he is talking about physics or writing about physics but with the correct use of physics. Since this form of knowledge is characterized by a strong grammar, that grammar makes visible its subject and, for the acquirer, the passage from a theory to another does not indicate a breaking of language but simply an extension of the explanatory and descriptive power of the language.

An interesting aspect which comes out of the conceptualization about the difference between hierarchical and horizontal structures of knowledge (Morais, 2002) is related to the form how teachers of areas of scientific knowledge are socialized. Experimental sciences are hierarchical structures of knowledge. Theories of instruction (social sciences) are horizontal structures of knowledge. That is to say, *the what* is to be taught in science classes is quite distinct in its structure from *the how* is to be taught. Science teachers and educators have been primarily socialized within specific hierarchical structures of knowledge and as such they have always encountered difficulties in accepting knowledge characterized by parallel languages. Primary academic socialization prepares science teachers and educators to *the what* of teaching and learning. However, *the how* of teaching and learning requires from teachers a further socializing process in the horizontal structures of knowledge. To reconcile them, teachers have to make a 'big jump' when passing from hierarchical structures to horizontal structures of knowledge, characterized by weak grammars.

Conceptual demand

The concept of conceptual demand was firstly used by Morais (Domingos, 1989a,b) to refer to the complexity of the teaching/learning process in terms of scientific skills/competences. A lower level of conceptual demand is related to skills that require a low level of abstraction (memorization and comprehension at a simple level). A higher level of conceptual demand implies skills that require a high level of abstraction (comprehension at a high level, analysis and knowledge utilization). Later on, on the course of jointly work by Morais and Neves (e.g., Morais, Neves & Pires, 2004), the concept evolved to integrate the complexity of both cognitive skills and scientific knowledge and, more recently (e.g., Calado, Neves & Morais, 2012; Ferreira & Morais, 2012**)**, to integrate intra-disciplinary relations, that is the strength of boundaries between distinct levels of knowledge within a given discipline. The studies described in this paper use this most recent perspective of conceptual demand. Conceptual demand of science education is defined as the level of complexity of science education as given by the complexity of scientific knowledge and of the strength of intra-disciplinary relations between distinct knowledges and also by the complexity of cognitive skills.

The complexity of scientific knowledge was based on the distinction between facts, generalized facts, simple concepts, complex concepts and unifying themes/theories. A fact is ‘data which results from observation’ (Brandwein, Watson & Blackwood, 1958, p.111) and corresponds to very concrete situations resulting from several observations. Generalized facts are the result of the relation of various facts of the same type. This kind of knowledge is knowledge of a low level of abstraction. A concept is a ‘mental construct; it is a grouping of the common elements or attributes shared by certain objects and events’ (Brandwein *et al*., 1980, p.12) and represents an idea that arises from the combination of several facts or other concepts. The categorization of concepts is the result of a hierarchical position of distinct levels of abstraction and complexity, where the most abstract and most complex concepts are the unifying themes and theories. The simple concepts correspond to concrete concepts proposed by Cantu and Herron (1978) and are those that have a low level of abstraction, defining attributes and examples that are observable, as the concepts of tree and insect at their lower level of understanding. The complex concepts correspond to abstract concepts proposed by Cantu and Herron (1978) and ‘are those that do not have perceptible instances or have relevant or defining attributes that are not perceptible’ (p.135), as the concepts of density and electron. The understanding of complex concepts involves the understanding of simple concepts and facts. Unifying themes are structural ideas and correspond, in science, to generalizations about the world that are accepted by scholars in each subject area (Pella & Voelker, 1968). Scientific theories correspond to explanations of a wide variety of related phenomena (Hickman, Roberts & Larson, 1995). Considering that the hierarchical structure of scientific knowledge is characterized by integrating propositions that operate at increasing levels of abstraction, theory development requires a new theory that is more general and more inclusive than the previous theory (Bernstein, 1999). If science education is to reflect the structure of scientific knowledge it should lead to the understanding of concepts and big ideas, although that understanding requires a balance between knowledge of distinct levels of complexity.

The intra-disciplinary relations between distinct knowledges are viewed as relations between discourses. Following Bernstein’s theory of pedagogic discourse (1990), these relations may be analyzed in terms of the strength of boundaries between discourses. In this particular case, the intra-disciplinarity is analyzed in terms of the strength of boundaries between distinct knowledges within a given discipline. Strong boundaries correspond to a situation where there is no relation between disctinct knowledges and weak boundaries correspond to a situation where there is a strong relation between disctinct knowledges. By promoting intra-disciplinary relations, the teaching/learning process may lead to the understanding of high order concepts, with greater power of description, explanation, prediction and transference (Morais, 2002). Intra-disciplinary relations in the science learning context have been defined in our studies as the relations between distinct scientific knowledges, either of the same or of distinct levels of complexity, and either within the same teaching unit or between teaching units, or even between declarative knowledge (theory) and procedural knowledge (practice) within a given scientific knowledge. These relations can range from very tight, that is with very weak boundaries between distinct knowledges (weak classification), to very loose (strong classification).

The level of conceptual demand depends also on the complexity of the cognitive skills that are involved in the teaching-learning process. Cognitive skills are considered as mental processes that may have different levels of complexity, depending on the steps involved (Marzano & Kendall, 2007). Categorization of cognitive skills has been presented in the form of taxonomies, as are the cases of the revised version of Bloom's Taxonomy of Educational Objectives (Krathwohl, 2002)[1] and the taxonomy created by Marzano and Kendall (2008)[2]. Science learning should not be limited to simple skills (as memorization) but should also include complex skills (as understanding, application and evaluation). The development of complex skills, that is important in itself, is crucial for the learning of high scientific knowledge. Whenever they are simultaneously present in the teaching-learning process, they contribute to effective cognitive development. For example, the application of a given complex concept entails higher level of conceptual demand than the understanding of the same concept. Whenever the high level of conceptual demand is put into practice, it may lead at what Vygotsky (1978) calls the development of high mental processes.

Following Bernstein's model of pedagogic discourse (1990, 2000), the conceptual demand of science education includes aspects related to '*the what*' (skills and knowledge) and to '*the how*' (intra-disciplinary relations) of the pedagogic discourse. Also following Bernstein, the hierarchical structure of science knowledge requires from the students high levels of complexity and abstraction so that they can attain a meaningful understanding of that knowledge. That is to say that conceptual demand of science education should be high, and should be high for *all* students. For this reason conceptual demand of science education can be seen as essentially sociological (Morais, Neves & Pires, 2004).

According to this theoretical framework, the relations to be discussed in this paper are shown in the diagram of Figure 1.

(insert Figure 1 about here)

Exemplar studies

Introduction

The studies presented in this paper followed a mixed research methodology (Creswell, 2003; Morais & Neves, 2010; Tashakkori & Teddlie, 1998), which combines aspects associated with quantitative and with qualitative methodological approaches. A quantitative approach was followed when, for example, in the analysis of educational texts and contexts, several categories and indicators were previously defined on the basis of the theory. A qualitative approach was followed whenever empirical data gave a contribution to the definition of categories and indicators.

According to this methodology, an external language of description was used, whereby the theoretical and the empirical are viewed dialectically (Bernstein, 2000) whenever constructing instruments and in data's collection and analysis. In this way, we reject the empirical analysis without a theoretical basis and the use of a theory that does not permit its transformation on the basis of the empirical (Morais & Neves, 2010).

In order to analyse the level of conceptual demand in educational texts, instruments were constructed, piloted and applied for each one of the selected dimensions of conceptual demand – complexity of scientific knowledge, intradisciplinary relations between distinct knowledges and complexity of cognitive skills. Although differing with the specificity of the texts analysed, the instruments have a similar structure. All of them contained indicators and descriptors defined on the basis of the monologic or dialogic character of the educational text.

Conceptual demand of educational texts

The analyses of conceptual demand of educational monologic texts (science curricula and textbooks) and dialogic texts (science pedagogic practices) were focused on Portuguese science education at various schooling levels – primary (e.g. Silva, Morais & Neves, 2012a, 2012b), middle (e.g., Alves, 2007; Alves & Morais, 2012; Calado & Neves, 2012; Calado, Neves & Morais, 2012; Ferreira, 2007) and secondary school (Ferreira & Morais, 2012).

The curricula which were analyzed are structured in either two documents (the case of primary and middle school) or two distinct parts of the same document (the case of secondary school [3]). The first is of a general character to define guidelines considered essential for the development of the curriculum of the discipline. The second, more specific, gives guidelines directly related to putting the curriculum into practice in the classroom. The curricula's analyses were focused on the Official Pedagogic Discourse

(OPD) present in the two documents/parts produced in the same context - Official Recontextualizing Field - with the objective of characterizing the message contained in each one of the documents/parts and of evaluating the recontextualizing processes that might have occurred between them.

The analyses of textbooks and pedagogic practices were focused on the Pedagogic Discourse of Reproduction (PDR), again with the objective of evaluating their level of conceptual demand and the recontextualizing processes that may occur when moving from the OPD to the PDR.

The diagram of Figure 2 represents the relations of the level of conceptual demand of educational science texts (curricula, textbooks and pedagogic practices), that have been analyzed.

(insert Figure 2 about here)

In order to analyze the two curricular documents, the respective texts were organized into four sections – 'Knowledge', 'Aims', 'Methodological guidelines' and 'Evaluation' - according to the nature of the information they contained. This organization was directed by the fact that these are dimensions that are usually part of official curricular documents, independently of the specific designation that might have been used in them. Each one of these sections was segmented into units of analysis. A unit of analysis was considered as an excerpt of the text containing one or more periods which together have a given semantic meaning (Gall, Gall & Borg, 2007). Each item of the lists of items, found in some sections of the curricula, and each diagram and figure were considered as a unit of analysis. Each unit of analysis was then analyzed using the various instruments constructed to appreciate the level of conceptual demand of the curricula, in terms of the following three dimensions – complexity of scientific knowledge, degree of intra-disciplinary relations between distinct knowledges (intra-disciplinarity) and complexity of cognitive skills.

In spite of the schooling level to be analyzed, the construction of the respective instruments was based on similar theoretical and methodological guidelines, although reflecting the specificities of the curricular text under analysis. The instruments for characterizing the complexity of scientific knowledge and the complexity of cognitive skills contained a three or four degree scale that reflects different levels of conceptualization of knowledge and of cognitive processes[4].

The instruments for characterizing intra-disciplinarity contained a four degree scale. Bernstein's concept of classification was used to define a scale where respective degrees give the strength of boundaries between distinct knowledges within the discipline. In the case of primary and middle science curricula, the intra-disciplinarity respects to relations between distinct scientific knowledges: the highest degree (C^{++}) corresponds to an absence of relations between distinct scientific knowledges; the lowest degree (C^{--}) corresponds to a strong relation between distinct scientific knowledges; the intermediate degrees (C^{+} and C^{-}) correspond to intermediate relations between distinct scientific knowledges. In the case of the study of the secondary science curriculum, the intra-disciplinarity respects to relations between declarative knowledge (theory) and procedural knowledge (practice), within scientific knowledge: the weakest classification (degree C^{--}) corresponds to an integration of theory and practice, where both have equal status, and the highest classification (degree C^{++}) corresponds to a separation between theory and practice. This study was centered on the level of conceptual demand of practical work in high school Biology and Geology.

With the intention of making clear the procedures that were followed, the paper is centred on the middle school curriculum studies (Alves, 2007; Calado, 2007; Calado, Neves & Morais, 2012; Ferreira, 2007)[5]. These studies were focused on the OPD contained in two curricular documents – *Essential Competences* (DEB, 2001) and *Curricular Guidelines* (DEB, 2002) - with regard to science education, and were particularly centered on the themes 'Sustainability in the Earth' and 'Living Better on Earth' (the themes of the Portuguese Natural Sciences curriculum of the two last years of middle school – ages 14^+ and 15^+).

One of the central objectives of these studies was to analyze the level of conceptual demand of the curriculum and the extent to which the messages of the two curricular documents evidenced recontextualizing processes.

Based on these studies, and considering the empirical level, the present paper clarifies the methodological procedures used in the analyses of the OPD of the two curricular documents and presents some of the results given by the analyses. At the theoretical level, the paper explores those results, and their relations with results of other similar studies, in order to discuss the importance of the level of conceptual demand of science education for accessing the structure of science knowledge.

The following tables (Tables 1, 2 and 3) intend to make methodological procedures explicit by presenting excerpts of instruments and examples of units of analysis and respective classification according to the scales of the instruments[6].

(insert Tables 1, 2 and 3)

Figure 3 shows the results of the analyses centered on the theme ‘Sustainability in the Earth’ of the middle science school curriculum, in order to appreciate the level of conceptual demand contained in the curriculum and the recontextualizing processes that occur between the two curricular documents.

(insert Figure 3 about here)

According to these results, we may say that: (a) the level of conceptual demand is very low when considering the ‘complexity of scientific knowledge’ and ‘intradisciplinarity’ dimensions and is relatively high for the indicator ‘complexity of cognitive skills’ dimension; (b) for all the three dimensions, the lowest degrees (1 and C^{++}) increase and the highest degrees (4, 3 and C^{--}) decrease when moving from the curricular document with the general principles (*EC*) to the curricular document with more specific guidelines (*CG*). This evidences recontextualizing processes, within the official recontextualizing field, in the direction of decreasing the complexity of cognitive processes, the complexity of science knowledge and the degree of relation between distinct levels of scientific knowledge, therefore lowering the level of conceptual demand.

The results of the other studies centered on the science middle school curriculum (Alves, 2007; Calado, 2007; Calado, Neves & Morais, 2012), give similar trends. They show a low level of conceptual demand, particularly in what concerns the complexity of knowledge and intra-disciplinarity and they also show recontextualizing processes in the direction of lowering the level of conceptual demand, when moving from the general to the specific curricular principles. The studies developed in the context of the primary (Silva, Morais & Neves, 2012a) and the secondary (Ferreira & Morais, 2012) science school curricula also suggest that the level of conceptual demand is, in general, low and it is lower in the curricular document with specific guidelines more directly related to the classroom context. Recontextualizing processes in the direction of lowering the level of conceptual demand were also observed in the study focused on textbooks (Calado & Neves, 2012) which complemented one of the studies of the middle science curriculum (Calado, 2007).

If we now consider studies which contained analyzes of pedagogic practices (e.g. Alves & Morais, 2012), their results show a similar picture, i.e., pedagogic practices are characterized by a low level of conceptual demand, even lower than the conceptual demand present in the respective curricula (middle science). A similar result was also found in a previous study, carried out at the middle and secondary science school levels (Domingos, 1989a, b). In this particular case, it was possible to understand that teachers tend to be influenced by the classroom social context, by implementing pedagogic practices whose level of conceptual demand is lower when teaching in school classes with students of low social background.

Conceptual demand and students' scientific learning

An important dimension of the study of the level of conceptual demand of curricula, textbooks and pedagogic practices respects to the analysis of the relation between that level and students scientific learning. A study that was carried out at the primary school level, and which analyses the relation between the level of conceptual demand of teachers' pedagogic practice and children's scientific learning (Silva, Morais & Neves, 2012b), will be here reported. The two teachers, who were involved in the study, used in their practices curriculum texts[7] that contained a high level of conceptual demand and an underlying mixed pedagogic practice with characteristics[8] that former studies (e.g. Morais, Neves & Pires, 2004; Morais & Neves, 2011) have shown to have the potential to lead students to success.

Instruments for characterizing the level of conceptual demand of teachers' pedagogic practice[9] referred to both *the what* and *the how* of that practice. In the case of *the what,* instruments contained three degrees of increasing complexity in order to characterize the lower or higher degree of teacher's proficiency either in terms of scientific knowledge[10] or investigative skills[11]. In the case of *the how,* the instrument contained four degrees of classification to indicate a smaller C^{++}) or greater (C^{--}) degree of intra-disciplinarity between distinct scientific knowledges.

Figure 4 shows the results of the analysis of the conceptual demand of the two teachers (Marco and Sara).

(insert Figure 4 about here)

The analysis indicated that the two teachers differed greatly in their level of conceptual demand. Whereas teacher Marco's pedagogic practice (with working class -WC- children only) was characterized by a high level of conceptual demand, teacher Sara's pedagogic practice (with working and middle class -MC- children) was characterized by a low level of conceptual demand.

The analysis of the relation between teachers' pedagogic practice (PP) and children's scientific learning, given by the results of a test that assessed science knowledge and investigative skills[12], is shown in the graph of Figure 5. Results are given in a four degree scale (0-24%; 25-49%; 50-74%; 75-100%) that corresponds to increasing degrees of children's performance in scientific knowledge (ScKn) and investigative skills (InvSk).

(insert Figure 5 about here)

The data shows that teacher Marco's children (all part of the WC) obtained much better results than teacher Sara's, even overcoming her MC children's results[13]. This was only possible because teacher Marco's pedagogic practice contained not only a high level of conceptual demand but was also close to the mixed pedagogic practice predicted in the curriculum texts, i.e. it contained another favourable feature to children's success. This was not the case of teacher Sara's pedagogic practice.

If we consider that, when compared with teacher Sara's PP, teacher Marco's PP was characterized by a higher level of conceptual demand, it is legitimate to think that it is possible to improve the learning of disadvantaged children without lowering the level of conceptual demand. This is an extremely important result that reinforces results of former studies (e.g., Domingos, 1989a; Morais, Neves & Pires, 2004) and that highlights the possibility of leading *all* students to adequate scientific knowledge and its hierarchical structure.

Final considerations

The studies developed so far, that were centred on the conceptual demand of the pedagogic discourse at various levels of the Portuguese educational system, broadly suggest that the level of conceptual demand decreases when moving from the general guidelines of the curricula to its specific guidelines and from these to textbooks and to the classroom context with regard to teacher's pedagogic practices (e.g. Alves, 2007; Alves & Morais, 2012; Calado & Neves, 2012; Calado, Neves & Morais, 2012;

Ferreira, 2007; Ferreira & Morais, 2012; Silva, Morais & Neves, 2012a, 2012b). The studies, which were focused on pedagogic practices with different levels of conceptual demand of science learning, suggest that higher levels of conceptual demand influence favourably *all* students' scientific learning (e.g. Domingos, 1989b; Silva, Morais & Neves, 2012b).

On the basis of these various studies, either centered on monologic or dialogic texts, it is possible to say that the conceptualizing of knowledge as a crucial condition for access of students to scientific knowledge is not much valued in the Portuguese science education. Science knowledge, as shown by Bernstein (1999), has a hierarchical structure characterized by the articulation between levels of knowledge in the direction of the development of successfully more general and integrating theories. Given this structure, it is legitimate to think that, in the context of science education, to lower the level of conceptual demand means to restrict students to nominal and factual knowledge and as such to give them a limited view of science knowledge as a discourse with a hierarchical structure. On the contrary, to raise the level of conceptual demand means to provide students with the access to conceptual knowledge and as such to give them a broad view of what science knowledge is. In this condition students may have access to the knowledge which is privileged by the scientific community and by power groups in society. And this must be a condition made available to *all* students. As argued by Morais (Domingos, 1989a), if students "are confined within a very limited conception of science, science as definitions, elementary procedural rules, rather than science as an imaginative exploration and explanation of the physical world […] they are likely to be cut off from the power of its discourse […] and if they have not access to the power of discourse they have not access to the discourses of power and their dominant agencies and practices in society." (p. 222)

It is important to note that science education contexts based on low level of conceptual demand do not correspond to the absence of vertical discourse because any academic discourse is a vertical discourse (Bernstein, 1999). However, it is a limited vertical discourse that, according to Morais (Domingos, 1989a), is restricted to the vocabulary of science (nominal and terminological knowledge) and not to its syntax (conceptual knowledge).

A decision about the level of conceptual demand that is to be valued in science education depends, to a great extent, on the ideological and pedagogical positioning of the educational agents (curricula and textbooks' authors, teachers). In fact, since education of science is a vertical discourse with a horizontal structure, there may appear in science education various parallel languages, with distinct science educators defending distinct pedagogic positions. For some of them – for instance, science educators without a broad perspective of the transmission-acquisition process or with ideological principles which devalue the social inequalities in school – to lowering the level of conceptual demand may represent a better way for helping disadvantaged students, given the assumption that they are not prepared to acquire a conceptualized scientific knowledge. For others – more acquainted with the sociological meaning and consequences of students' inequalities – it is crucial that the level of conceptual demand is not lowered. This is based on the assumption that socially disadvantaged students (~~as~~ likewise the socially advantaged students) have potentialities for acquiring a conceptualized scientific knowledge, provided teachers' pedagogic practice takes into consideration their socio-cultural characteristics, by creating conditions to increase their positioning in the school context and to facilitate their access to the school's vertical discourse.

Within this line of thought, Morais (Domingos, 1989a), argued that "[…] teachers who make a very low level of conceptual demand have failed to understand the sociological implications of the transmission-acquisition process they are promoting. Children who enter the school disadvantaged will leave it still more disadvantaged. […] The fact that these pupils can be successful with teachers who make a low level of conceptual demand […] means how *measured* achievement can give us a measure of memorized knowledge […] and not necessarily an understanding of that knowledge, which would require a teaching that takes into account the very structure of the scientific knowledge […].The understanding of scientific concepts and principles, and the competence to use this knowledge in solving new problems and in understanding and criticizing the world, should not be a preserve of a socially selected few. […] To defend the culture of the working-class does not entail that the children should be deprived of scientific literacy nor that such literacy entails the adoption of what are considered to be middle-class values and practices and the loss of their own values and practices.” (pp. 216-221).

To keep social equality in science learning contexts means to create conditions for *all* students to have access to a pedagogic discourse that expresses the structure of scientific knowledge. And to lead *all* students to access the hierarchical structure of scientific knowledge means to give them the opportunity to learn science in a conceptually demanding context.

However, it is important to note that the authors of this paper are not defending a science education restricted to high levels of conceptual demand. A balance should exist between simple and complex knowledge because no complex knowledge can be understood without the acquisition of the simple knowledge involved. A balance should also exist between simple and complex cognitive skills, and memorization should be included. As referred by Ferreira and Morais (2012), based on data evidenced by neuroscience research (e.g. Eichenbaum, 2004; Geake, 2009; Kumaran et al., 2009), “the automation of mental tasks is necessary in order that a larger area of the brain is available to perform more complex tasks, involving the use of knowledge. Only when students develop simple skills, as memorization of specific facts and concepts, can s/he develop complex skills as applying these concepts to new situations" (p.24).

This paper presented a mode of measuring the level of science education by measuring its level of conceptual demand. The discrimination of various dimensions of the level of conceptual demand on the basis of concepts of the areas of both psychology and sociology allows a detailed analysis of science educational texts and may be applied to other areas of educational knowledge, respecting their specificities.

The relation made in this paper between the pedagogical dimension (Knowledge transmission) and the epistemological dimension (Knowledge structure) of science knowledge allowed the discussing of the meaning of distinct levels of conceptual demand in terms of students' differential access to the hierarchical structure that characterizes science knowledge. While using a theoretical framework in science education, based on Bernstein's conceptualization of forms of discourses, a contribution might have been given to the construction of new educational knowledge and to open up new directions for research in this area.

Notes

1. The revised Bloom's taxonomy contains six levels of complexity of cognitive processes: remembering; understanding; application; analysis; evaluation; and creation. In the studies where this taxonomy was used, the first two levels refer to what is called as simple skills and cover psychological processes such as remembering and understanding at the most elementary level. The last two levels refer to more complex skills that involve a level of complexity higher than that of simple skills, such as the highest level of understanding, application, analysis, evaluation and creation. Within the simple skills, it was also considered two levels of complexity: the skills which involve the lowest level of complexity by referring to the retrieving of relevant knowledge from long-term memory, such as recalling; and the skills which imply a higher level of complexity as it is the case of understanding at the level of exemplification. Within the complex skills, it was considered two other levels of complexity: the skills, which involve understanding at the highest level, as it is the case of inferring or explaining, and the cognitive process of application; and the skills which involve the highest level of complexity, including cognitive skills that range from analysis and evaluation to creation.

2. Marzano's taxonomy contains four levels for the cognitive system: retrieval; comprehension; analysis; and knowledge utilization. Retrieval, the first level of the cognitive system, involves the activation and transfer of knowledge from permanent memory to working memory and it is either a matter of recognition or recall. The process of comprehension is responsible for translating knowledge into a form appropriate for storage in permanent memory and involves two related processes, integrating and symbolizing. The third level, analysis, involves the production of new information that the individual can elaborate on the basis of the knowledge s/he has comprehended. The fourth and more complex level of the cognitive system implies the knowledge utilization in concrete situations and involves four general categories: decision making, problem solving, experimenting, and investigating.

3. The study developed at the secondary school level was focused on the Biology and Geology curriculum for 10th and 11th years of schooling. Although part of the same discipline, Biology and Geology are presented in the Portuguese curriculum as two distinct subjects. For that reason they were analyzed separately either for each one of the two schooling years taken separately (10th and 11th), in the case of specific directions, or for both schooling years taken together, in the case of general directions common to the two of them. Thus, in this study, we considered six parts of the curriculum: general part of Biology, Biology 10th, Biology 11th, general part of Geology, Geology 10th and Geology 11th.

4. The study developed at the primary school level made use of instruments with shorter scales for analyzing the complexity of both knowledge and cognitive skills because the curricular texts at this level contain little knowledge and investigative skills of high level of abstraction and complexity.

5. The studies centered on science curricula at the middle school level (Alves, 2007; Calado, 2007; Ferreira, 2007) were part of the same broader investigation, conducted in the context of the authors' research group.

6. The whole picture of the instruments and of the classification of the units of analysis may be found in Alves (2007), Calado (2007) and Ferreira (2007). Also available in http://essa.ie.ul.pt: Instruments 2.2.9, 2.2.10b and 2.2.11.

7. The curriculum texts refer to a set of activities to be used in the science classroom – worksheets, experimental guides, etc. – and which were constructed for this specific study.

8. The characteristics are the following: (a) clear distinction between subjects with distinct statuses (strong classification of the teacher-student relation); teacher control of selection and sequencing of knowledge, competences and classroom activities (strong framing, namely at the macro level, of selection and sequencing); student control over the time of acquisition (weak framing at the level of pacing); clear explication of the legitimate text to be acquired in the context of the classroom (strong framing at the level of the evaluation criteria); personal relationships of communication between teacher and students and between students (weak framing at the level of the hierarchical rules); inter-relation between the various kinds of knowledge of a discipline to be learned by students (weak classification at the level of intra-disciplinarity); blurring of the boundaries between teacher-student and student-student spaces (weak classification between spaces).

9. The instruments used for characterizing the pedagogic practice in its various dimensions may be found in Silva (2010). Also available in http://essa.ie.ul.pt: Instruments 2.1.12, 2.1.13 and 2.1.14.

10. The excerpt that follows is part of the instrument that was constructed to analyze teacher's proficiency of scientific knowledge:

Indicator	**Degree 1**	**Degree 2**	**Degree 3**
Children's doubts/questions	The teacher gives scientifically incorrect answers that evidence major deficiencies at the level of scientific knowledge.	The teacher gives answers where s/he makes some relations but fails other relations essential for the clarification of the doubt/question, this indicating some deficiencies at the level of scientific knowledge.	The teacher gives answers that contain various relations to subject matters previously studied, evidencing great rigour and correction in all those relations.

11. The excerpt that follows is part of the instrument that was constructed to analyze teacher's proficiency of investigative processes:

Indicator	**Degree 1**	**Degree 2**	**Degree 3**

Discussing experimental activities	The teacher shows no knowledge of investigative processes, evidenced by a discussion with children of problems, predictions, observations, interpretations of results and conclusions, contained in children's activities, that mechanically follows the worksheets questions.	The teacher shows some knowledge of investigative processes but ignores some important steps of these processes as, for example, relations between results, the problems, predictions previously made.	The teacher shows full knowledge of investigative processes by exploring and correctly relating different steps of these processes (problems, hypotheses, observations, interpretation of data, conclusions).

12. The scientific knowledge assessed is related to the concept of the growing of living things. This concept is central to the set of activities that were part of the curriculum texts (constructed for this study) implemented by the two teachers. Investigative skills are skills developed through the activities (e.g. making predictions, interpreting experimental results).

13. The test results were reinforced by the results of the study of children's specific coding orientation to concept understanding when considering the concept of the growing of living things vivos (Silva, Morais, & Neves, 2012b).

References

Alves, V. (2007). *O currículo, o software didáctico e a prática pedagógica: Análise sociológica de textos e contextos do ensino das ciências.* Master's dissertation, Catholic University of Lisbon.

Alves, V., & Morais, A. M. (2012). A sociological analysis of science curriculum and pedagogic practices. *Pedagogies: An International Journal*, 7 (1), 52-71.

Andrich, D. (2002). A framework relating outcomes based education and the taxonomy of educational objectives. *Studies in Educational Evaluation, 28,* 35-59.

Bernstein, B. (1990). *Class, codes and Control, Vol. IV: The structuring of pedagogic discourse.* London: Routledge.

Bernstein, B. (1999). Vertical and horizontal discourse: An essay. *British Journal of Sociology of Education, 20* (2), 157-173.

Bernstein, B. (2000). *Pedagogy, Symbolic Control and Identity: theory, research, critique,* (rev. edition), London: Rowman & Littlefield.

Brandwein, P., Watson, F., & Blackwood, P. (1958). *Teaching high school science: A book of methods*. New York: Harcourt Brace Jovanovich.

Brandwein, P., *et al* (1980). *Concepts in science* (Curie Edition). New York: Harcourt Brace Jovanovich.

Calado, S. (2007). *Currículo e manuais escolares: Processos de recontextualização no discurso pedagógico de ciências naturais do 3º ciclo do ensino básico*. Master's dissertation, School of Science University of Lisbon.

Calado, S., & Neves, I. P. (2012). Currículo e manuais escolares em contexto de flexibilidade curricular: Estudo de processos de recontextualização. *Revista Portuguesa de Educação, 25* (1), 53-93.

Calado, S., Neves, I. P., & Morais, A. M. (2012). Conceptual demand of science curricula: A study at the middle school level. *Pedagogies* (forthcoming)

Cantu, L. L., & Herron, J. D. (1978). Concrete and formal Piagetian stages and science concept attainment. *Journal of Research in Science Teaching*, 15 (2), 135-143.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative and mixed approaches* (2nd ed.). Thousand Oaks, CA: Sage.

DEB (Department of Basic Education) (2001). *Currículo nacional do ensino básico – Competências essenciais*. Lisbon: Ministry of Education.

DEB (Department of Basic Education) (2002). *Ciências físicas e naturais – Orientações curriculares para o 3º ciclo do ensino básico*. Lisbon: Ministry of Education.

Domingos, A. M. (now Morais). (1989a). Conceptual demand of science courses and social class. *In* P. Adey (Ed.), *Adolescent development and social science.* London: Falmer Press.

Domingos, A. M. (now Morais) (1989b). Influence of the social context of the school on the teacher's pedagogic practice. *British Journal of Sociology of Education, 10* (3), 351–66.

Eichenbaum, H. (2004). Hippocampus: Cogntive processes and neural representations that underlie declarative memory. *Neuron*, 44(1), 109-120.

Ferreira, S. (2007). *Currículos e princípios ideológicos e pedagógicos dos autores: Estudo do currículo de ciências naturais do 3º ciclo do ensino básico*. Master's dissertation, School of Science University of Lisbon.

Ferreira, S., & Morais, A. M. (2012). Conceptual demand of practical work: Studying science education curricula. *Research Papers in Education* (proposed for publication).

Gall, M., Gall, J., & Borg, W. (2007). *Educational research: An introduction* (8th Ed.). Boston: Pearson/Allyn and Bacon.

Geake, J. (2009). *The brain at school: Educational neuroscience in the classroom*. Berkshire, UK: Open University Press.

Harlen, W. (1999). Purpose and procedures for assessing science process skills. *Assessment in Education*, 6,

Hickman, C., Roberts, L, & Larson, A. (1995). *Integrated principles of zoology*. Iowa: Wm. C. Brown.

Krathwohl, D. (2002). A revision of Bloom's taxonomy: An overview. *Theory into practice*, *41* (4), 212-218.

Kumaran, D., Summerfield, J., Hassabis, D., & Maguire, E. (2009). Tracking the emergence of conceptual knowledge during human decision making. *Neuron*, 63(6), 889-901.

Marzano, R. J., & Kendall, J. S. (2007). *The new taxonomy of educational objectives* (2nd ed.). Thousand Oaks, CA: Corwin Press.

Marzano, R. J., & Kendall, J. S. (2008). *Designing & assessing educational objectives: Applying the new taxonomy*. Thousand Oaks, CA: Corwin Press.

Morais, A. M. (2002). Basil Bernstein at the micro level of the classroom – Looking at results of research. *British Journal of Sociology of Education, 23*(4), 559-569.

Morais, A. M., Neves, I. P., & Pires, D. (2004). The *what* and the *how* of teaching and learning: Going deeper into sociological analysis and intervention. *In* J. Muller, B. Davies & A. Morais (Eds.), *Reading Bernstein, Researching Bernstein* (Chap. 6). London: Routledge & Falmer.

Morais, A. M., & Neves, I. P. (2007). A Teoria de Basil Bernstein. Alguns aspectos fundamentais. *Revista Práxis Educativa, 2* (2), 115-130.

Morais, A. M., & Neves, I. P. (2010). Basil Bernstein as an inspiration for educational research: Specific methodological approaches. *In* P.Singh, A. Sadovnik & S. Semel (Eds.), *ToolKits, translation devices and conceptual accounts: Essays on Basil Bernstein's sociology of knowledge* (Chap.2). New Iorque: Peter Lang.

Morais, A. M., & Neves, I. P. (2011). Educational texts and contexts that work: Discussing the optimization of a model of pedagogic practice. *In* D. Frandji & P. Vitale (Eds.), *Knowledge, pedagogy & society: International perspectives on Basil Bernstein`s sociology of education* (Chap. 12). London: Routledge.

Pella, M., & Voelker, A. (1968). Teaching the concepts of physical and chemical change to elementary school children. *Journal of Research in Science Teaching*, 5, 311-323.

Silva, P. (2010). *Materiais curriculares e práticas pedagógicas no 1º ciclo do ensino básico: Estudo de processos de recontextualização e suas implicações na aprendizagem científica*. Doctoral thesis, Institute of Education, University of Lisbon.

Silva, P., Morais, A. M., & Neves, I. P. (2012a). O currículo de ciências no 1º ciclo do ensino básico: Estudo de (des)continuidades na mensagem pedagógica. *Revista Portuguesa de Educação, 25* (2) (forthcoming).

Silva, P., Morais, A. M., & Neves, I. P. (2012b). Materiais curriculares, práticas e aprendizagens: Estudo no contexto das ciências do 1º ciclo do ensino básico. *Revista Práxis Educativa* (forthcoming).

Tashakkori, A., & Teddlie, C. (1998). *Mixed methodology: Combining qualitative and quantitative approaches*. Thousand Oaks, CA: Sage.

Vygotsky, L. (1978). *Mind in Society: The development of higher psychological processes*, Ed. M. Cole, V. John Steiner, S. Scribner and E. Souberman, Cambridge, MA: Harvard University Press.

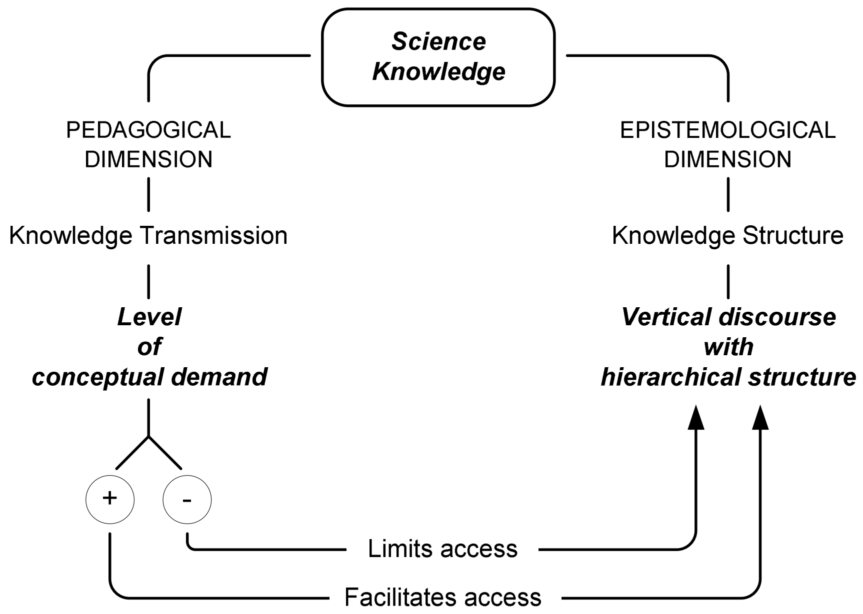


Figure 1 – Conceptual demand and structure of knowledge in the science educational context

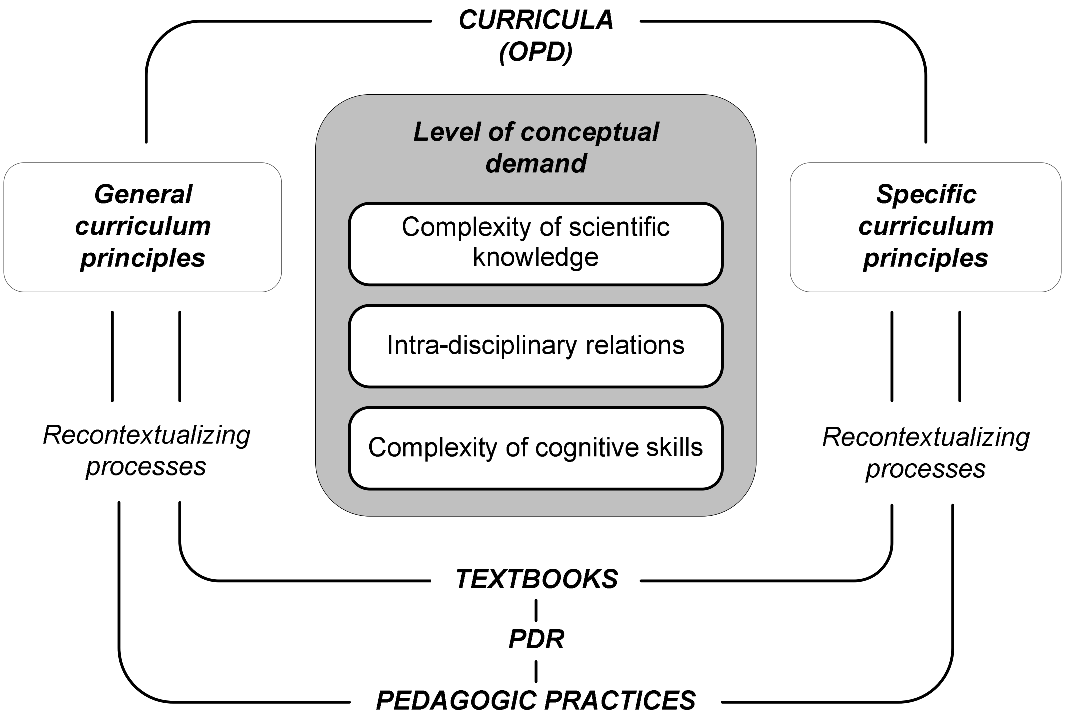


Figure 2 – Level of conceptual demand of educational texts and recontextualizing processes.

Table 1 - *Excerpt of the instrument for analyzing the complexity of scientific knowledge and respective examples of units of analysis*

Excerpt of the instrument

Section	**Degree 1**	**Degree 2**	**Degree 3**
Methodological guidelines	Suggestions of strategies/methodologies that aim at the transmission/acquisition of generalized facts and/or simple concepts, with a low level of complexity.	Suggestions of strategies/methodologies that aim at the transmission/acquisition of complex concepts, with a level of complexity higher than that of simple concepts and constituted by not perceptible defining attributes.	Suggestions of strategies/methodologies that aim at the transmission/acquisition of unifying themes/theories, involving a very high level of complexity.

Units of analysis

Degree 1: " When studying energy flows, the sun's role as source of energy, probably already studied in the Physics-Chemistry discipline, should be recalled" ('Sustainability in the Earth' - *Curricular Guidelines*).

Degree 2: "[…] within a general approach of some aspects of inheritance, students should be faced with situations dealing with the transmission of characteristics along generations (eye and hair colour)." ('Living Better on Earth' - *Curricular Guidelines*)

Degree 3: "Understanding that the dynamics of ecosystems is a result of the interdependence between living things, materials and processes". ('Sustainability in the Earth' - *Essential Competences*).

Table 2: *Excerpt of the instrument for analyzing the intra-disciplinarity (relation between distinct levels of scientific knowledge) and respective examples of units of analysis*

Excerpt of the instrument

Section	**C^{++}**	**C^{+}**	**C^{-}**	**C$^{- -}$**
Methodological guidelines	The strategies/methodologies suggested contain the relationship between simple knowledge within the same theme. *Or* Scientific knowledge essential to the understanding of the relationship between knowledge is missing in the strategies/methodologies suggested.	The strategies/methodologies suggested contain the relationship between simple knowledge of distinct themes.	The strategies/methodologies suggested contain the relationship between complex knowledge, or between this and simple knowledge, within the same theme.	The strategies/methodologies suggested contain the relationship between complex knowledge, or between this and simple knowledge of distinct themes.

Units of analysis

Degree C$^{+ +}$: "It is recommended that students understand the existence of different types of water and the relation of their use with varied purposes" ('Sustainability in the Earth'- *Curricular Guidelines*)

Degree C^{-} : "Starting from familiar situations to the students (bites, burns, anxiety in school assessment) and focusing on voluntary and involuntary reactions, the role of the nervous system (central and peripheral) and of the hormonal system in the coordination of the organism should be highlighted" ('Living Better on Earth' - *Curricular Guidelines*)

Degree C^{+}: [Inexistent in the text of either of the two themes analyzed].

Degree C$^{- -}$: "[...] it is intended that, after having understood concepts related to the structure and functioning of the Earth system, students can apply them to situations that refer to humans' intervention on Earth and to the resolution of problems that result from that intervention, having in mind the Earth sustainability" ('Sustainability in the Earth' - *Essential Competences*).

Table 3 - *Excerpt of the instrument for analyzing the complexity of cognitive skills and respective examples of units of analysis*

Excerpt of the instrument

Section	Degree 1	Degree 2	Degree 3	Degree 4
Methodological guidelines	Strategies/methodologies that call for mobilizing skills of a low level of complexity, involving processes that require the retrieving of relevant knowledge from long-term memory.	Strategies/methodologies that call for mobilizing skills as the understanding of simple instructional messages like exemplification.	Strategies/methodologies that call for mobilizing skills as the understanding of complex instructional messages, like explanation, and application.	Strategies/methodologies that call for mobilizing skills of a very high level of complexity as analysis, evaluation and creation.

Units of analysis

Degree 1: "The students should learn the location of genetic material inside the cell […]" ('Living Better on Earth' - *Curricular Guidelines*)

Degree 2: "Recognizing situations of sustainable development in diverse regions" ('Sustainability in the Earth' – *Essential Competences*).

Degree 3: "[…] Considering that innumerous catastrophes may put at stake the equilibrium of ecosystems and the survival of human populations, the students should reflect on the causes and effects of catastrophes […]." ('Sustainability in the Earth' – *Curricular Guidelines*).

Degree 4: "Planning and developing research activities. Problem-solving situations, while requiring different ways of searching, collecting, analyzing and organizing information, are fundamental to understanding science." ('Living Better on Earth' - *Essential Competences*)

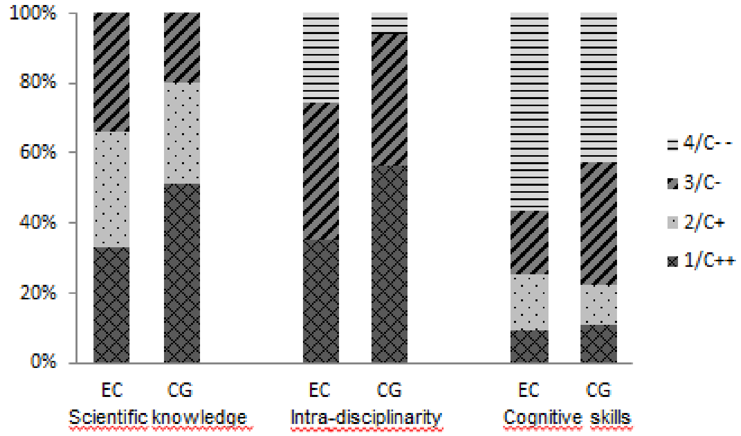
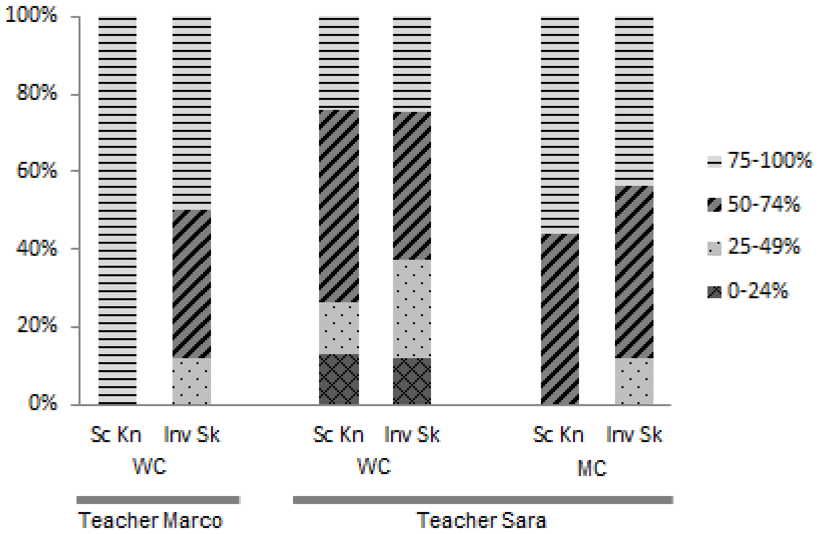


Figure 3 - Level of conceptual demand of *Essential Competences* (*EC*) and *Curricular Guidelines (CG)* documents for middle school, when complexity of scientific knowledge, degree of intra-disciplinarity and complexity of cognitive skills are considered (Source: Ferreira, 2007).

Teacher/PP	***Conceptual demand***		
	The what of PP		*The how* of PP
	Proficiency in science knowledge	Investigative proficiency	Intra-disciplinarity
Marco	High	High	Strong
Sara	Low	Low	Weak

Figure 4 – Level of conceptual demand of teachers' pedagogic practice (PP)



Sc Kn – Scientific Knowledge; Inv Sk – Investigative Skills; WC – Working Class; MC – Middle Class

Figure 5 – Relation between teachers' pedagogic practice and students' scientific learning

Vertical discourses and science education

Analyzing conceptual demand of educational texts

Abstract

The paper investigates the level at which hierarchical structures of knowledge, as seen in terms of the concept of conceptual demand, are present in science education texts and contexts. Conceptual demand is explored from both theoretical and empirical points of view. Theoretically, the paper discusses the sociological meaning of conceptual demand of science education by using Bernstein's theorizing (1999) about vertical discourses and hierarchical structures of knowledge, and according to which science education is education of specific knowledge with a hierarchical structure. Empirically, the paper describes the external language of description developed to analyse the conceptual demand at various levels of the educational system. The paper also gives some results of studies which have investigated the level of conceptual demand of science texts and contexts and its relation with children's scientific learning. These results are discussed in terms of their sociological meaning in science education.

Key-words: Vertical discourses; Hierarchical structures of knowledge; Science education; Conceptual demand; Pedagogic texts and contexts; Students' scientific learning.