ISSN: 2178-7727
DOI: 10.17648/acta.scientiae.v21iss1id4947

Dimensions of Science Learning: A Study on PISA Test Questions Involving Chemistry Content

Fabiele Cristiane Dias Broietti[1]
Paulo dos Santos Nora[1]
Sandro Lucas Reis Costa[1]

[1] Mestrado em Ensino de Ciências e Matemática, Centro de Ciências Exatas, Universidade Estadual de Londrina/UEL, Londrina, PR, Brazil

Received for publication on 10 Dec. 2018. Accepted, after revision, on 14 Feb. 2018.

ABSTRACT

In this article we discuss the potential of certain questions from PISA to engage students in specific scientific dimensions. The guiding question for the research is: What Dimensions of Scientific Learning, described in the NRC (2012), can be identified in questions that address the chemical contents of the PISA Science test? Thus, we analyze the questions seeking to identify the Scientific Practices, Crosscutting Concepts and Disciplinary Central Ideas. The research is predominantly qualitative and the analysis of the data was based on the procedures of content analysis. A total of 59 questions were analyzed with the aid of the Atlas software. From the analysis, some clusters were attempted to configure such dimensions. The following results are highlighted: the most identified scientific practices in the analyzed questions were analyzing and interpreting data (SP4) and constructing explanations (SP6). The most identified crosscutting concept was: cause and effect – mechanism and prediction (CC2). And as for the third dimension – disciplinary core ideas – we highlight the higher incidence of the physical sciences (DCI1) that deals with topics involving matter and its interactions. We highlight the potential of PISA items to involve students in specific scientific dimensions; in addition, we consider that this study brings contributions to teachers in the scientific areas, since recognizing the dimensions can guide their actions in the classroom, aiming at teaching that favors scientific literacy.

Keywords: Chemistry. PISA. Scientific Literacy. Scientific Practice.

Dimensões da Aprendizagem Científica: um Estudo em Questões do PISA que Abordam Conceitos Químicos

RESUMO

Neste artigo discutimos o potencial de questões da prova do PISA para envolver os estudantes em dimensões científicas específicas. A questão norteadora da investigação é: Quais

Corresponding author: Fabiele Cristiane Dias Broietti. E-mail: fabieledias@uel.br

Dimensões da Aprendizagem Científica, descritas no NRC (2012), podem ser identificadas em questões que abordam conteúdos químicos das provas de Ciências do PISA?

Assim, analisamos as questões buscando identificar as Práticas Científicas, os Conceitos Transversais e as Ideias Centrais Disciplinares. A investigação é predominantemente qualitativa e a análise dos dados se pautou nos procedimentos da análise de conteúdo. Foram analisadas 59 questões, com o auxílio do software Atlas ti. Da análise foram realizados alguns agrupamentos buscando configurar tais dimensões. Destacam-se os seguintes resultados: as práticas científicas mais identificadas nas questões foram analisar e interpretar dados (PC4) e construir explicações (PC6). O conceito transversal mais identificado foi: causa e efeito – mecanismo e predição (CC2). E quanto à terceira dimensão – ideias centrais disciplinares – destacamos a maior incidência das ciências físicas (ICD1), que trata de conteúdos a respeito da matéria e suas interações. Destacamos o potencial dos itens do PISA para envolver os estudantes em dimensões científicas específicas; além disso, consideramos que este estudo traz contribuições para os professores das áreas científicas, uma vez que reconhecer as dimensões pode orientar suas ações em sala de aula, visando um ensino que favoreça a alfabetização científica.

Palavras-chave: Química. PISA. Alfabetização Científica. Prática Científica.

INTRODUCTION

The PISA ─ Programme for International Student Assessment ─ is an international evaluation created in 1997 by a consortium of institutions, led by the Australian Council for Educational Research, managed by the Organization for Economic Cooperation and Development (OECD) and coordinated in Brazil by the National Institute for Educational Studies and Research Anísio Teixeira (INEP).

The program evaluates the skills and knowledge of fifteen-year-old students, are students that are close to the end of the compulsory cycle, and are supposedly prepared to face the challenges of today, that is, they need to present accumulated knowledge, skills and attitudes of at least ten years of education.

This assessment takes place every 3 years and was applied for the first time in the year 2000. A major area (sciences, reading or mathematics) is analyzed in depth each year and a summary profile of skills is provided, it consists in the application of scientific knowledge in personal, social and global contexts. The questions are elaborated through scientific topics, which involve the use of selected specific knowledge about one aspect about the natural world (OECD, 2007). Each theme, called a test unit, is composed of specific stimulus materials, with short text that can be accompanied by a chart, diagram or table.

Thus, according to the OECD (2007, p.7), the PISA assessment:

> [...] takes a comprehensive approach to assessing knowledge, skills, and attitudes that reflect current curriculum modifications, from school-based approaches to applying knowledge to everyday tasks and challenges. Acquired skills reflect students' ability to continue lifelong learning, applying what they have learned at school in non-school environments, assessing their options, and making decisions.

The PISA assesses what students are able to do with what they have learned during compulsory education and their ability to reflect and apply the knowledge gained in everyday issues. In this sense, considering the acquisition of scientific knowledge by students and their subsequent reflection and use in different contexts, it is related to the concept of scientific literacy. According to PISA 2015, in regards to being scientifically literate: "[...] it requires not only knowledge of concepts and theories of science but also knowledge about common procedures and practices associated with scientific research and how they enable the advancement of science" (OECD, 2013, p.4). In PISA, scientific literacy is defined by three basic skills:

> 1 - Explain phenomena scientifically: recognize, offer and evaluate explanations for natural and technological phenomena;
>
> 2 - Evaluate and plan scientific experiments: describe and evaluate scientific research and propose ways of approaching scientific questions;
>
> 3 - Interpret data and evidence scientifically: analyze and evaluate data, statements and arguments, drawing appropriate scientific conclusions. (OECD, 2013, p.7)

The skills mentioned above go beyond content knowledge, depending on the understanding of how scientific knowledge is built and its degree of trust. In this paper we discuss the potential of certain test questions to engage students in specific dimensions by examining PISA science test questions, more specifically, questions that address chemistry content.

DIMENSIONS OF SCIENCE LEARNING (DSL)

The dimensions offer indicators to the development of scientific literacy. They were drafted by a committee of researchers under the general coordination of the National Research Council of the United States of America (NRC, 2012), in a paper entitled: The Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.

This document presents the importance of teaching and learning science; points out the relevance of the construction of human knowledge to the world, integrating the processes of teaching and learning of science and describes three dimensions necessary for this, namely: 1) Scientific Practices (SP): in which are described the main practices that scientists employ to investigate, construct models and theories about the world; 2) Crosscutting Concepts (CC): are unifying concepts that have application in all fields of science; and, 3) Disciplinary Core Ideas (DCI): essential parts of the scientific disciplines to be addressed.

The NRC (2012) extends the discussions already begun in previous years related to science learning in formal environments (NRC, 2007) and in non-formal environments

(NRC, 2009). The first document seeks to (re) define what it is to be proficient in science and how classroom work should be with K-8 students (equivalent to the 9th grade in Brazil). The second paper examines the objectives of science teaching in informal settings and investigates the potential of extra-school settings for science learning.

Thus, we believe that these references broaden the discussions about science learning; consequently, on the evaluation of scientific aspects, since in addition to addressing content, they include aspects inherent in science learning, as to learn science is to be involved in a broad set of knowledge that goes beyond the conceptual perspective.

The NRC (2012) points out the importance of the construction of human knowledge in the world, with integration in the process of teaching and learning in science, and also seeks to articulate education in science, engineering and technology, which are necessary at the present time. This document also points out that learning in science occurs through a process, made possible through three important dimensions: SP; CC and DCI. The following are the dimensions:

Scientific Practices (SP)

The SP described in the NRC (2012) refer to not only activities or actions involving the experimental stage in science, but encompass a broader concept, they indicate actions or 'resources' that scientists use to investigate and construct theories and models about phenomena. The authors point out that the "term 'practices' instead of a term such as 'skills' is used to emphasize that engaging in scientific research requires not only skill but also knowledge that is specific to each practice." (NRC, 2012, p.30).

The following are the eight SPs, considered essential for students to develop at K12 level (in Brazil, equivalent to the 3rd year of High School), they must be developed in interaction, in a combined way, and not thought as a linear sequence. Here are some descriptions of these scientific practices.

SP1 − Asking questions – It consists of asking questions about a phenomenon and developing theories that can provide answers to the questions; reformulate and refine questions to be answered (NRC, 2012). According to NGSS (2013a) this practice can be motivated by curiosity or inspired by the prediction of a model, theory, or even by the need to solve a problem, leading to involvement with other practices.

SP2 − Developing and using models – It involves the construction and use of a wide variety of models and simulations to help develop explanations of natural phenomena (NRC, 2012). Ricketts (2014) reports in his work that teachers do not explore the full potential of models, using it for communication and not for thinking or reflecting on study situations. The models serve in the elaboration of new questions and explanation, and the communication of ideas; even if it contains limitations (NGSS, 2013a).

SP3 − Planning and carrying out investigations– It is based on planning and conducting a systematic investigation, which requires the identification of what is being investigated and can deal with dependent and independent variables (NRC, 2012). In activities done in the classroom, as in Crujeiras-Pérez and Jiménez-Aleixandre (2017), it is argued that through this practice it is possible to promote students' understanding of the nature of scientific work and its operation. It is important to remember that investigations do not only correspond to those involving laboratory experiments (Ricketts, 2014).

SP4 − Analyzing and interpreting data – It consists of systematically analyzing data from scientific research, testing them with the initial hypotheses, recognizing conflicts in order to transform them into information and/or knowledge, through appropriate resources, and then communicating them to other individuals or groups (NRC, 2012). Ricketts (2014) reports that one of the difficulties encountered by teachers who worked with this practice was on how to teach students to engage in this practice, as it was often used by students only to interpret data and follow in their investigations.

SP5 − Using mathematics and computational thinking – It comprises the use of mathematical and / or computational approaches that allow predictions of the behavior of physical systems, also with the test of such predictions, through the inserted data, recognition, expression of applications and quantitative relations (NRC, 2012). Ricketts (2014) has shown that this practice is important not only for organizing data, but is useful for interpreting them as well as aiding in the elaboration of explanations that are contained by the data.

SP6 − Constructing explanations – It consists of applications of theory to a specific situation or phenomenon. It includes the logical construction of coherent explanations of phenomena embodying current understanding of science, or a model that represents it, and is consistent with the available evidence (NRC, 2012). Ricketts (2014) comments that teachers have not made so much difference between this practice and SP7-engaging in argument from evidence, which they corroborate in the explanation of phenomena, with or without experiments. It is worth remembering that this distinction between these two practices has been the subject of continuous debate in the scientific community in recent years.

SP7 − Engaging in argument from evidences– It is understood that scientific reasoning is grounded by evidence, and it is possible to examine one's own understanding and that of others. In science, reasoning and argumentation are essential to identify the strengths and weaknesses of a line of thought and to find the best explanation for a natural phenomenon (NRC, 2012). Thus, it is important for students to understand the culture that scientists live in, understanding that evidence and reasoning provide the basis for an acceptable argumentation (NGSS, 2013a).

SP8 − Obtaining, evaluating and communicating information– It includes the communication of research ideas and results, which can be expressed, orally or in writing, and engaging in discussions with peers. Science cannot move forward if scientists are unable to communicate their findings clearly and learn about the results of other scientists (NRC, 2012). Ricketts (2014) comments that in science communication is common to others, as well as in reflections, aided by the use of other scientific practices. Thus, it is important to develop reading skills, interpretation and production of specific texts, as well as to learn to communicate clearly and persuasively (NGSS, 2013a).

These are practices common to scientific research, that is, they are important actions for the understanding and explanation of any phenomena. Other studies that used scientific practices, seeking to deepen the understandings are: Ricketts (2014); Reiser, Berland and Kenyon (2012); Bybee (2011).

Crosscutting Concepts (CC)

The CC refer to common themes that transcend the boundaries of each discipline, provide ways of linking the domains of Scientific Practices to Disciplinary Core Ideas. According to CCSSO (2018), this scientific dimension provides consistent subsidies that can help in the language between teachers and students, allowing a focus on communication and orientation to the student's thinking, in specific aspects for the understanding of any phenomena; since understanding the student's thinking requires a variety of different strategies to make this thought understandable, with a language appropriate to the scientific environment. The following is a brief description of the CCs.

CC1 − Patterns – Patterns are important to guide organization and classification and this depends on careful observation of similarities and differences (NRC, 2012). According to CCSSO (2018), this dimension helps teachers and students formulate questions about factors that influence the cause and observed effects, as well as providing evidence that supports explanations and arguments.

CC2 − Cause and effect: mechanism and explanation – The main activity of Science is the investigation and explanation of causal relationships and the mechanisms by which they are mediated. These mechanisms can then be tested through certain contexts and used to predict and explain events in other contexts (NRC, 2012; CCSSO, 2018).

CC3 − Scale, proportion and quantity – When considering phenomena, it is fundamental to recognize that they vary in size, time, amount of energy and that changes in scale, proportion and quantity affect the structure or performance of the system (NRC, 2012). According to NGSS (2013b) it is important for the student to recognize this perception of quantity, and the relative magnitude in the properties and processes, including the quantities involved.

CC4 − Systems and system models – Scientists and students learn to define small portions of the natural world to investigate, called systems. A system is an organized group of related objects or components that form a set (NRC, 2012). This concept provides tools for understanding and testing ideas that are applicable in science (CCSSO, 2018).

CC5 − Energy and matter: flows, cycles and conservation – The ability to analyze, characterize and model transfers and cycles of matter and energy is a useful tool for all areas of science. Studying the interactions between matter and energy provides students with the development of increasingly sophisticated conceptions of their roles in any system (NRC, 2012).

CC6 − Structure and function – Form and function are complementary aspects of objects; one explains the other. The functioning of the objects depends on the properties of the material from which it is made (NRC, 2012). It is important to carefully observe the forms, composition and properties, which may be related to the function of the object, used in research (NGSS, 2013b).

CC7 − Stability and change – For natural and constructed systems, stability conditions are determinant of rates of change or evolution of a system. Knowing stability, with its standards, one can construct explanations that provide stability changes (NRC, 2012).

The CCs can provide a connective structure that supports students' understanding of the sciences as a discipline and facilitates their understanding of the phenomena under study in specific disciplines (NGSS, 2013b). CCs contribute to guide the implementation and experience of the Scientific Practices. Next are the Disciplinary Core Ideas, third dimension:

Disciplinary core ideas (DCI)

According to the NRC (2012), the task of science education lies not in teaching all the facts, but in preparing students with essential parts of knowledge, so that they can acquire additional information of their own later, according to their interest and need. These ideas, or content of the sciences, contribute in the explanation of any phenomena. The following are brief descriptions of the DCI, with their main subdivisions, according to the NRC (2012):

DCI1 — Physical Sciences — DCI1.1 Matter and its interactions; DCI1.2 Motion and stability: Forces and interactions; DCI1.3 Energy; DCI1.4 Waves and their applications in technologies for information transfer.

DCI2 — Life Sciences — DCI2.1 From molecules to organisms: Structures and processes; DCI2.2 Ecosystems: Interactions, energy, and dynamics; DCI2.3 Heredity: Inheritance and variation of traits; DCI2.4 Biological evolution: Unity and diversity.

DCI3 — Earth and Space Sciences — DCI3.1 Earth's place in the universe; DCI3.2 Earth's systems; DCI3.3 Earth and human activity.

DCI4 — Engineering, Technology, and Applications of Science — DCI4.1 Engineering design; DCI4.2 Links among engineering, technology, science, and society.

The contents selected in this dimension are not separated by the disciplines Chemistry, Physics and Biology, but relate them in an interdisciplinary way. According to the NRC (2012) it is necessary to meet some requirements to be considered a Disciplinary Core Idea, such as: having importance in science disciplines, and being a key principle in your disciplinary organization; providing a key tool for solving problems and understanding complex ideas; relating to common interests and experiences in the lives of students, connected to social and technological concerns; and, finally, that it can be understood along increasing levels of depth, sustained by continuous research over the years.

Considering that such dimensions contribute to the learning of science, we thus present our discussions on scientific literacy.

SCIENTIFIC LITERACY

In the area of science, PISA advocates scientific literacy considering that the skills acquired throughout schooling reflect the ability of students to continue to learn throughout life, juxtaposing knowledge in non-school settings. In this perspective, it is not enough to only learn the specific contents of the disciplines, but to be able to apply this information in other contexts (OECD, 2016).

According to Deboer (2000) scientific literacy comprises a science teaching that: contributes to understanding and acting in the modern world; helps to prepare for the job market; teaches students to be informed citizens; presents numerous applications in everyday life and technology; in addition to broadening the student's vision to examine the world in the face of phenomena and in mass communications, enhancing their discussion and argumentation by forming critical citizens.

According to Hurd (1997) the scientifically literate person would be able to distinguish theory and dogma, recognizing science in its political and ethical dimension, knowing how scientific research is carried out, its data processing, and how to use appropriate scientific knowledge for their decision-making and problem solving in which science is related.

It is worth remembering that there is no unified definition of "scientific literacy" in the educational community, however, we will assume the definition adopted in the PISA documents. The term scientific literacy is defined in PISA, based on four main dimensions of a differentiated nature: contents, processes, contexts and attitudes (OECD, 2007).

The first concerns students' knowledge and ability to use such knowledge while performing cognitive processes characteristic of science and scientific research in contexts of personal, social and global relevance. The second is related to scientific processes, centered on the ability to acquire, interpret and act based on evidence. The third dimension defines a variety of everyday situations, not limited to the school context, involving science and technology. Finally, the dimension of attitudes plays a significant role in the interest, attention and reactions of individuals to science and technology (OECD, 2007).

According to the American National Research Council (NRC, 1996), scientific literacy refers to the individual's ability to ask questions and find/propose answers arising from the questions of curiosity about everyday experiences, that is, ability to describe, explain and predict natural phenomena. In addition, you should be able to read a scientific paper and engage in discussions about the validity of the findings; make decisions using Science; assess the quality of the information received and the evidence-based arguments for appropriate conclusions (NRC, 1996).

Considering the objective of this study ─ to discuss the potential of certain test questions to involve students in specific dimensions ─ in the next section we introduce the methodological procedure and research context.

METHODOLOGICAL PROCEDURE AND RESEARCH CONTEXT

For the identification of the dimensions in the PISA questions, we used textual analysis with emphasis on the Content Analysis (CA) procedures and criteria advocated by Bardin (2016) and Moraes (1999). The CA forms part of a set of textual analysis techniques, produced in a variety of ways, such as interviews, reports and other documents.

The CA consists of five steps that contribute to the organization and analysis of data collected, namely: information preparation, unitarization, categorization, description and interpretation of data (Moraes, 1999). The information preparation took place through the selection of the research corpus, the PISA science questions from the years 2000 to 2015, especially those involving chemistry concepts. At this stage we selected 59 questions.

The 59 questions selected for analysis were extracted from two booklets of items released on the INEP portal – federal authority linked to the Ministry of Education (MEC), in Brazil. In the first notebook, there are a total of 122 questions, which correspond to the years of application of PISA from 2000 to 2012, and are organized into 33 themes. Of these questions, we identified 50 that deal predominantly with Chemistry, 48 with Biology and 24 with Physics. This classification was made based on the contents covered in the Curriculum Guidelines for High School (Brasil, 2006, p.113-115).

The second manual released by INEP corresponds to the evaluation applied in the year 2015 with 32 questions, which cover a total of 8 themes. We identified 9 questions that address Chemistry contents, 17 of Physics and 5 of Biology. Therefore, we analyzed in this research the 59 questions of Sciences that approach Chemistry contents referring to the years from 2000 to 2015. After selecting the questions, these were codified from Q1 to Q59.

The data were organized with the aid of the Atlas software. Atlas.ti software is an auxiliary tool in the qualitative analysis of research data that can facilitate the management and interpretation of this data by giving greater visibility and transparency to data analysis. Employed by different areas of knowledge, such as education and administration, its first commercial edition was launched in 1993 in Belgium (Walter & Bach, 2015; Klüber, 2014).

In the unitization stage, the question statements as well as the expected responses were read carefully until the definition of units of analysis was made. The unit of analysis, also called "unit of record" or "unit of meaning", is the unit element of content to be submitted for classification (Moraes, 1999, p.5).

In the process of grouping data, the DSL ─ Scientific Practices, Crosscutting Concepts and Disciplinary Core Ideas ─ described in the NRC (2012) as a priori categories were used. At this stage, the statements of the questions (units of analysis) were examined and an attempt was made to identify the dimensions, that is, the scientific practices, the crosscutting concepts and the disciplinary core ideas. All the questions have undergone a double-blind review process. Each question was analyzed by two of the researchers with the objective of identifying the dimensions described by the NRC (2012).

In the process of description, a synthesis text was produced, which expresses the meanings present in the units of analysis organized according to the categories, through scientific practices, crosscutting concepts and disciplinary core ideas.

Finally, in the process of interpretation, we seek to discuss the potential of PISA items to involve students in specific dimensions. In the following section we present the procedure carried out, through examples of some questions, we emphasize that the same movement was carried out in all the analyzed questions.

RESULTS AND DISCUSSION

In this section we present results from the analysis of the 59 questions. For the sake of space, we present some examples of questions. The questions presented here were chosen because they present different DSL – and thus enable discussions about the potential of PISA items to involve students in specific dimensions. We present a text and experiment mentioned for the question Q43 (Figure 1) that deals with the theme Sunscreen, applied in the year 2006.

SUNSCREENS

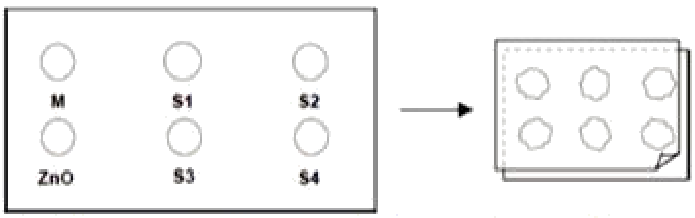
Mimi and Dean wondered which sunscreen product provides the best protection for their skin. Sunscreen products have a *Sun Protection Factor (SPF)* that shows how well each product absorbs the ultraviolet radiation component of sunlight. A high SPF sunscreen protects skin for longer than a low SPF sunscreen.

Mimi thought of a way to compare some different sunscreen products. She and Dean collected the following:

- two sheets of clear plastic that do not absorb sunlight;
- one sheet of light-sensitive paper;
- mineral oil (M) and a cream containing zinc oxide (ZnO); and
- four different sunscreens that they called S1, S2, S3, and S4.

Mimi and Dean included mineral oil because it lets most of the sunlight through, and zinc oxide because it almost completely blocks sunlight.

Dean placed a drop of each substance inside a circle marked on one sheet of plastic, and then put the second plastic sheet over the top. He placed a large book on top of both sheets and pressed down.



Mimi then put the plastic sheets on top of the sheet of light-sensitive paper. Light-sensitive paper changes from dark gray to white (or very light gray), depending on how long it is exposed to sunlight. Finally, Dean placed the sheets in a sunny place.

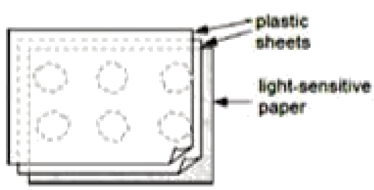


Figure 1. Text and experiment given for the question Q43. (INEP, 2015, p.126-127)

The text and experiment presented contextualize a daily situation in which the characters Mimi and Dean seek to identify what sunscreen offers the best option for the skin. The characters are looking for a way to compare some different sunscreens, using mineral oil and zinc oxide. Question Q43, asks for the choice of an option that matches the question that Mimi and Dean sought to answer with the experiment.

As an expected response, PISA states: “A. How does the protection for each sunscreen compare with the others?” (INEP, 2015, page 128).

In question Q43 the following Dimensions of Science Learning were identified: SP1 – Asking questions and SP3 – Planning and carrying out investigations. Among the options presented, students should choose which question Mimi and Dean were trying to answer with the experiment (SP1) and know the systematics of an investigation to be able to further evaluate the phenomenon under study (SP3).

As for CCs, we identified CC1 – Patterns; CC2 – Cause and effect: mechanism and explanation and CC4 – Systems and system models. Before the exposition of how the experiment was carried out, the student needs to observe details of the experiment, perceiving the relationships, in order to guide the organization (CC1); When comparing the effect of each sunscreen in the cited experiment, it can be concluded that the cause would be a lower or higher quality in the protection factor (CC2) and this experience is a “snippet” of what is in the world, that is , a system of study, in which objects interact, as the parts in this experiment; in addition it can be controlled or manipulated and provide predictions to other solar protectors (CC4).

Regarding DCI, we identified DCI1 – Physical Sciences, the student’s understanding of the experiment occurs through the knowledge of various scientific concepts related to the composition of matter, its properties and its relation to light, which helps both in the observation of variables and in the generation of possible explanations.

Next, we discuss Q51 that deals with the topic Fossil Fuels applied in the year 2015. The support available for the question is in Figure 2. For question Q51 a text and a diagram is provided illustrating the carbon cycle in the environment, the text addresses fossil fuels; the use of biofuels and carbon capture in oceans. It is asked to select the statement that best explains the difference in the CO_2 level of the atmosphere, in relation to the use of both types of fuels.

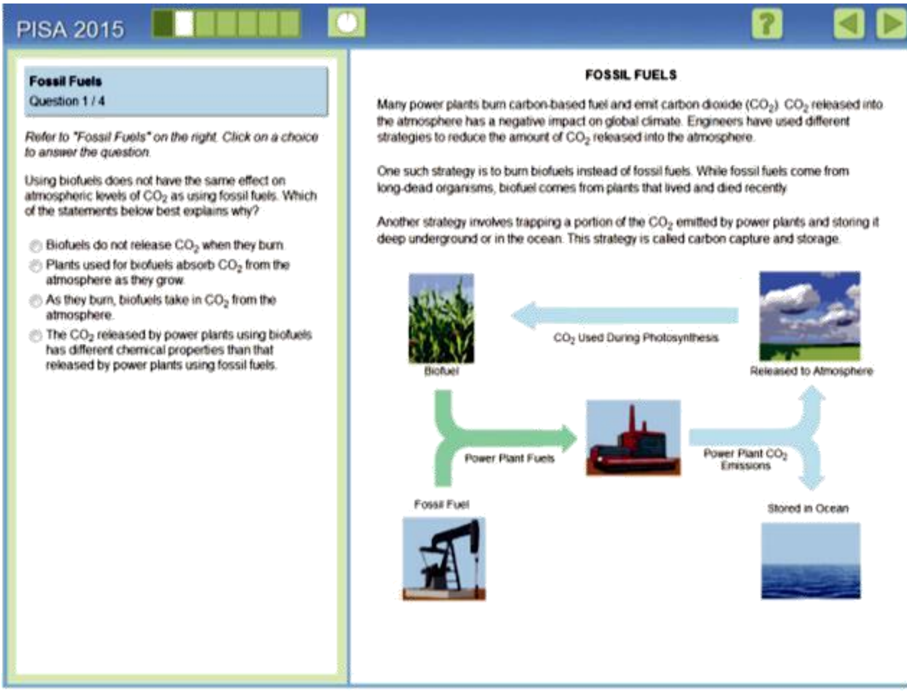


Figure 2. Question Q51 and the supporting text. (INEP, 2016, p.11)

As an expected response, PISA suggests:

> Students must use appropriate scientific content knowledge to explain why the use of plant-based biofuels does not affect atmospheric levels of CO_2 in the same manner as burning fossil fuels. The second option is the correct response: Plants used for biofuels absorb CO_2 from the atmosphere as they grow. (INEP, 2016, p.11)

In question Q51 the following Dimensions of Science Learning were identified: SP2 –Developing and using models and SP6 – Constructing Explanations. The diagram containing the carbon cycle serves as a model that can help the student to answer the question (SP2) and the student should choose the explanation of the relationship and effects on the level of CO_2 in the atmosphere when using biofuels or fossil fuels (SP6).

As for the CCs, CC4 – Systems and system models and CC5 – Energy and matter: flows, cycles and conservation. The cycle represented in the question corresponds to a system, since among the complexity of the natural world this is a portion, which is being studied in greater depth (CC4). The carbon cycle involved in the use of fossil fuels and biofuels involves transfers of matter and energy in each subsystem and in the system as a whole (CC5).

Regarding the DCI, we identified DCI2 – Life Sciences, since the issue addresses how organisms obtain and use energy, the result of chemical reactions and energy transformation, the process of photosynthesis; and, cycles of matter and energy transfer in the ecosystem: energy from chemical reactions in animal and plant organisms.

The same movement was carried out in the other questions, totaling the 59 questions analyzed. In the continuity, Figure 3, we present a summary of the analyses of the SP.

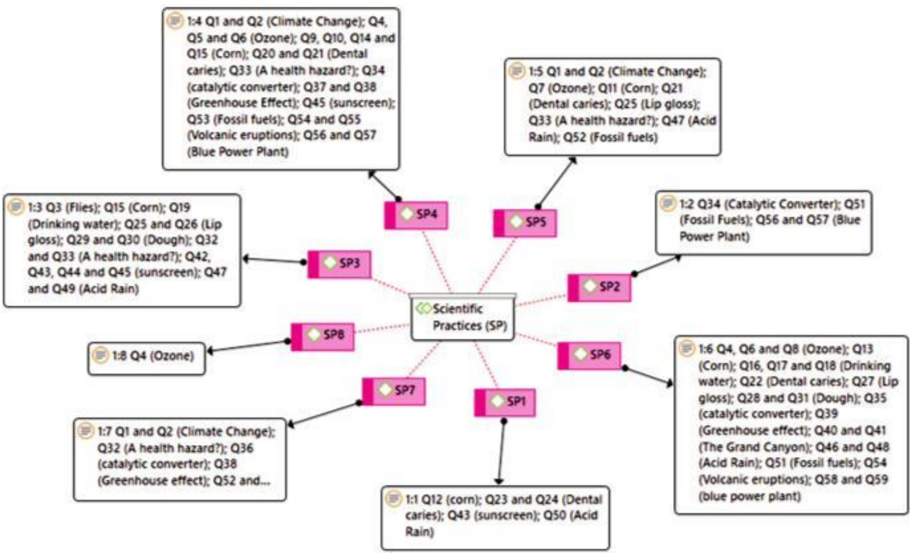


Figure 3. Scientific Practices identified in the PISA questions their and corresponding themes.

According to our analysis, the most evident SPs were SP4, SP6 and SP3, respectively.

SP4 – analyzing and interpreting data – is important in understanding phenomena, since there is no point in having data available without its interpretation and analysis being required, in order to reveal patterns and relationships that can be used as evidence in the construction of the argumentation, and in communication to others, essential to scientific literacy (NRC, 2012).

From SP6 – constructing explanations –, students are able to construct their own conclusions, providing causal explanations, from the proper use of laws, theories, and available evidence that may aid in explanation. Thus, it is important to involve students with scientific explanations of the world around them, helping them to gain an understanding of the main ideas that science has developed. We can relate to SP6, the contributions of Sasseron (2008), which mentions the explanation of phenomena as one of the indicators of scientific literacy, in which one seeks to relate the information and the hypotheses raised about a certain phenomenon

SP3 – planning and carrying out investigations – is important for scientific literacy as it contributes to the resolution of the research question by designing experimental or observational investigations that are appropriate to answer the question posed or to test some formulated hypothesis. Scientific investigation allows students to work with the variables involved, helping them to make decisions and select appropriate tools to solve the problem in question.

In relation to the other SPs, although manifested in a smaller number of questions, they also allow contexts for the discussion of such practices. SP8 involves scientific argumentation, communicating in writing, or through speech, fundamental practice in science (NRC, 2012). Regarding argumentation, Lemke (1997 apud Sasseron, 2008) states that both the act of speaking and the act of writing do not suffice to understand their technical meanings but to perceive the variation of their meanings in certain contexts. Thus, when speaking/discussing about a phenomenon, it is necessary to build a mental organization, generating knowledge.

SP2 – developing and using models – facilitate the understanding of the phenomena involved, through SP2, students should be able to construct/elaborate drawings, diagrams or charts as a way of understanding, explaining, or even predicting about a phenomenon, especially those of a microscopic scale.

SP5 – Using mathematics and computational thinking – is essential for understanding and solving various problems, through SP5 students should be able to recognize appropriate dimensional quantities, when applied to graphs, tables and formulas, and to expose their idea through this language. It has the necessary conditions to understand the mathematical reasoning involved in simulations, forecasts and programs, and also to be able to use them in the analysis of data.

The SP7 – Engaging in Argument from Evidence – refers to the use of evidence for the elaboration of a consistent argumentation, to examine your own understanding and that of others regarding a given system that has been investigated. This practice reinforces that, for science argumentation to be solid, it must be based on evidence, which supports what is being explained (NRC, 2012). Regarding argumentation, Sasseron (2008) uses the term argument to relate the validity that the evidence gives to the argumentation: “The argument appears when, in any statement made, a guarantee is given for what is proposed. This makes the statement receive approval, which makes it safer” (Sasseron, 2008, p.68). Thus, the evidence gives greater support to the statements, generating greater security in the quality of the answers about the investigated phenomena.

SP1 – Asking questions – refers to the elaboration and evaluation of questions about natural and/or constructed phenomena, through SP1 students should be able to inquire about the natural and constructed world in questions: How? Because? It is to evaluate whether or not an issue can be investigated by refining questions in order to be answered in certain fields, such as in the classroom. Figure 4 below summarizes the analyses of the questions regarding CCs.

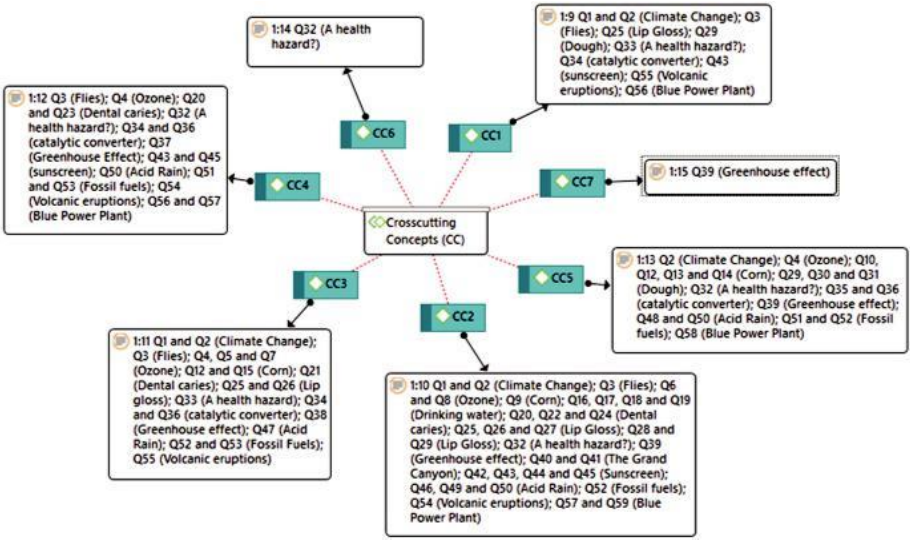


Figure 4. The Crosscutting Concepts identified in the PISA questions, and corresponding themes.

From Figure 4, we also observe evidence of all CC, especially CC2. According to the NRC (2012), knowledge of cause and effect (CC2) is very important in constructing explanations of the natural world, as well as in scientific literacy. Through the questions why? and how?, one can promote the search for answers of the causes to the effects found, and later the search for mechanisms that justify the causes. A way of encouraging scientific investigation (SP3) and argumentation from evidence (SP7). In this regard, Jiménez-Alexandre, Bugallo Rodriguez and Duschi, 2000 apud Sasseron (2008 p.58), mention that causality is a "cause-effect relationship, search for mechanism, prediction", an important epistemological operation (as a form of action and thought to become science).

The other CCs, although evidenced in a smaller quantity, also allow discussion contexts. The CC3 – scale, proportion and quantity –, allows the student the reasoning of proportion and proportionality to understand and explain the phenomena. This concept is related to the skill number three, in which it is necessary to interpret the data coming from scientific investigation.

The CC4 – systems and system models – is important for understanding the natural world, given its complexity, and it is necessary to define small portions for investigation. Thus, through models, one can better explore the system and evidence existing interactions, identify variables that influence the study system, making them more understandable, facilitating their interpretation and understanding (NRC, 2012). Regarding models, Sasseron (2008) mentions that in the epistemological operations used for argumentation, it is identified by the use of an analogy, an example, an attribute, as a form of explanation; thus, in the argumentation it is necessary to use adequate scientific tools, in this way the models adapt to this necessity.

The CC5 – Energy and matter: flows, cycles and conservation – is important in the understanding and execution of scientific investigation. It is necessary to address the conservation of matter and energy, since this occurs in all chemical, physical or biological processes. We also consider it essential for scientific literacy, since it is related to PISA's skill 1 when laws and theories are used that can help in the proper interpretation of a given problem, and competence 2 when systematizing or evaluating a research line (NRC, 2012).

Through the CC6, students can be encouraged to recognize examples, in which the shape of an object can be affected by its structure, moving from the micro to the mechanical functions of objects. According to the NRC (2012), form and function are complementary aspects. Thus, understanding the microscopic structure contributes to the understanding of the properties of materials.

The CC7 – Stability and change, consists in the search of the understanding of changes that take place in the phenomena and in how to control these changes. Scale is essential in this understanding, being in static equilibrium and in dynamic equilibrium at the same time, depending on the scale being used for analysis.

CC1 – Patterns can be stimulated early on by helping the scientist discover the first relationships or differences in the system being investigated after careful observation of the natural world. Moreover, through the patterns, a form of recognition of the microscopic world is possible (NRC, 2012). The following figure summarizes the analyses of the DCI present in the questions.

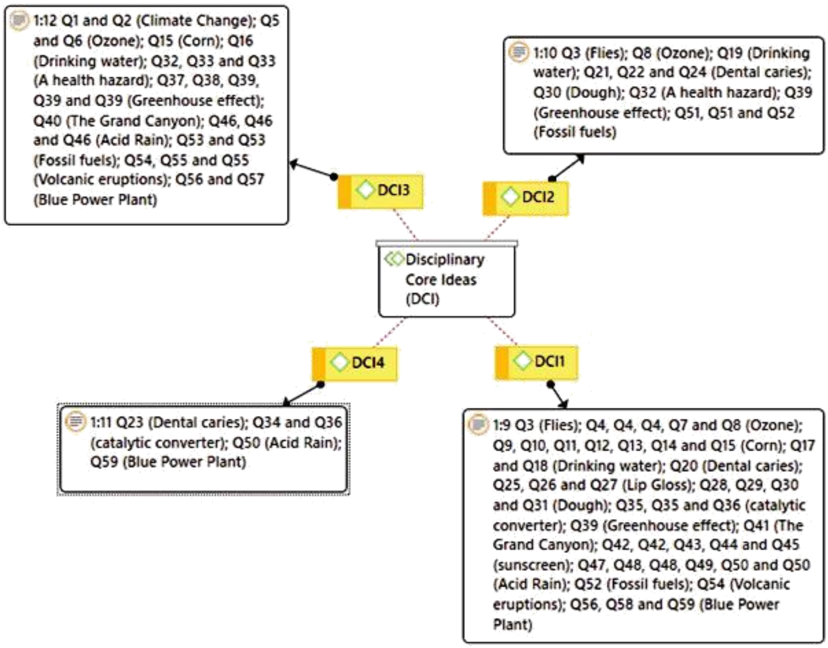


Figure 5. The Disciplinary Core Ideas identified in the PISA questions, and corresponding themes.

In the figure above, we present a summary of the analysis of the DCI. It should be noted that the same issue can present more than once the same DCI, due to the subcategories they present, so we chose not to enter the total.

The DCI that was most present in the issues was the DCI1 – physical sciences, identified in 64% of the questions. The great incidence can be explained, since, this dimension includes mainly contents of Chemistry and of Physics, with respect to matter and its interactions, movement, forces, energy and waves. Moreover, these concepts contribute to the understanding and construction of explanations to different phenomena, important characteristics valued in the competencies of the PISA test.

The DCI that was least identified in the issues is DCI4 – engineering, technology and applications of science, covering about 8% of the issues. This may indicate that the science proficiency in PISA, especially chemistry, has not prioritized the understanding of material development.

At this point, it is worth noting that we do not know whether students actually tend to use their knowledge in a desirable way when approaching a test question, unless some cognitive interview was conducted around certain requests. Because of this, what we sought in this study was to discuss the potential of certain assessment items to engage students in certain competencies, here expressed as SP; CC and DCI.

CONCLUSIONS

The central focus of this research was discuss the potential of certain test questions to engage students in specific dimensions. By recognizing the dimensions in PISA questions, we expect students and even teachers working with these questions in their classes to promote science education that values the building of scientific knowledge and deepen knowledge in each of these dimensions.

Scientific practices are essential for the understanding of the sciences and for the development of scientific literacy, since they encompass the formulation of questions; the development and use of models; planning and conducting investigations; analyses and interpretation of data; the use of mathematical and computational thinking; the construction of explanations; scientific reasoning, evaluation and reporting of information.

Crosscutting Concepts help students to remember/perceive the presence of unifying concepts that can help them in forming a line of reasoning, thus helping in the elaboration of an explanation to a certain phenomenon, or even, providing subsidies for the argumentation, or in order to evaluate or elaborate an investigative question. Thus, they do not appear in isolation, and are usually associated, namely: the patterns; causes and effects; the scales, proportions and quantity; systems and models; energy and matter; structure and function, and stability and change.

In turn, the disciplinary core ideas are essential contents of science, necessary for the elaboration of different explanations on the phenomena. The understanding of phenomena occurs through knowledge of existing laws and theories, which are consequences of the historical construction of countless scientists who have contributed to the present. In this way, the third dimension is present when the first and second dimensions are used (science as a process).

According to Harris, Krajcik, Pellegrino and Mcelhaney (2016), the central point in the use of dimensions is that disciplinary core ideas and crosscutting concepts cover the domains of science, and scientific practices must be integrated so that science teaching engages students in the application of knowledge, not only in their acquisition, giving meaning to the phenomena that they want to explain and actively solving the problems to which they are submitted, thus engaging in practices that are common and particular to science.

In this perspective, we emphasize that DSL can favor a Science Teaching in which the understanding of the world does not depend only on accumulated specific content that must be applied to a problem, but understood as a process. This process can be developed, at least through the Scientific Practices, Crosscutting Concepts and some Disciplinary Core Ideas.

REFERENCES

Bardin, L. (2016). *Análise de conteúdo*. São Paulo: Edições 70.

Bybee, R. W. (2011). Scientific and Engineering Practices in K-12 Classrooms: Understanding "A Framework for K-12 Science Education". *Science Scope*, *35*(4), 6-11.

CCSSO – Council of Chief State School Officers. (2018). *Using Crosscutting Concepts To Prompt Student Responses*. CCSSO Science SCASS Committee on Classroom Assessment. Washington.

Crujeiras-Pérez, B., & Jiménez-Aleixandre, M. P. (2017). High school students' engagement in planning investigations: findings from a longitudinal study in Spain. *Chemistry Education and Research Practice*, 18, 99-112.

Deboer, G. E. (2000). Scientific Literacy: Another Look at Its Historical and Contemporary Meanings and Its Relationship to Science Education Reform. *Journal of research in science teaching, 37*(6), 582-601.

Harris, C. J., Krajcik, J. S., Pellegrino, J. W., & Mcelhaney, K.W. (2016). *Constructing assessment tasks that blend disciplinary core Ideas, crosscutting concepts, and science practices for classroom formative applications*. Menlo Park, CA: SRI International.

Hurd, P. D. (1998). Scientific Literacy: New Minds for a Changing World. *Science Education*, *82*(3), 407-416.

Inep. (2015) PISA 2015 – *Programa Internacional de Avaliação de Estudantes*: exemplos de itens liberados de Ciências. Disponível em: <http://download.inep.gov.br/acoes_internacionais/pisa/itens/2015/itens_liberados_ciencias_pisa_2015.pdf>. Acesso em: 10 jan. 2016.

Klüber, T. E. (2014). ATLAS.ti como instrumento de análise em pesquisa qualitativa de abordagem fenomenológica. *Educ. temat. digit.*, *16*(1), 5-23.

Moraes, R. (1999). Análise de conteúdo. *Revista Educação, 22*(37), 7-32.

NGSS – Next Generation Science Standard. (2013a). Appendix F – *Science and Engineering Practices in the NGSS*, abr.

NGSS – Next Generation Science Standard. (2013b). Appendix G – *Crosscutting Concepts*, abr.

NRC – National Research Council. (2012). *A Framework for K-12 Science Education:* Practices, Crosscutting Concepts, and Core Ideas. Committee on Conceptual Framework for the New K-12 Science Education Standards, 320p.

______. (2009). *Learning Science in Informal Environments*: People, Places and Pursuits. Committee on Learning Science in Informal Environments: Washington, D.C. 352p.

______. (2007). *Taking Science to School*: Learning and Teaching Science in Grades K-8. Committee on Science Learning, Kindergarten through Eighth Grade. Washington, DC: The National Academies.

______. (1996). *National Science Education Standards*. Washington, DC: National Academy, 272p.

OECD – Organização para Cooperação e Desenvolvimento Econômico. (2007). *PISA 2006 estrutura da avaliação*: conhecimentos e habilidades em ciências, leitura e matemática. São Paulo: Moderna.

OECD – Organisation for Economic Co-Operation and Development. (2013). *Matriz de avaliação de ciências*. Tradução do documento: PISA 2015. Draft Science Framework. OCDE– Organização para Cooperação e Desenvolvimento Econômico. (2016). *Brasil no PISA 2015*: análises e reflexões sobre o desempenho dos estudantes brasileiros. São Paulo: Fundação Santillana.

Reiser, B. J., Berland, L. K., & Kenyon, L. (2012). Engaging Students in the Scientific Practices of Explanation and Argumentation. *Science and Children*, *49*(8), 8-13, Apr. Ricketts, A. (2014). Preservice Elementary Teachers' Ideas about Scientific Practices. *Science and Education*, *23*(10), 2119-2135.

Sasseron, L. H. (2008). *Alfabetização científica no ensino fundamental*: estrutura e indicadores deste processo em sala de aula. 2008, 265f. (Tese de Doutorado) – Faculdade de Educação, Universidade de São Paulo, São Paulo.

Walter, S. A. & Bach, T. M. (2015). Adeus papel, marca-textos, tesoura e cola: inovando o processo de análise de conteúdo por meio do atlas.ti. *Administração: ensino e pesquisa*, *16*(2), 275-308.