IJPCE
International Journal of Physics and Chemistry Education, 10(2), 49-54

www.ijpce.org
ISSN: 2589-8876

PISA, Structuring Themes and Unifying Concepts in Physics Teaching through Interactive Simulations

Wagner Duarte José*
Universidade Estadual do Sudoeste Bahia, Brazil
wagjose@gmail.com

José André Angotti
Universidade Federal de Santa Catarina, Brazil
angotti@ced.ufsc.br

Abstract
In Brazil, educational plans and guidelines have been consolidating large-scale assessments as potential references for High School and for initial and continuing teacher training, among them the Programme for International Student Assessment (PISA). The student's critical acceptance mediated by the teacher can result in cultural gains of the essential knowledge of Science and Technology as citizenship instruments. We propose the development of *Hypermidiatic Study Activities* through interactive simulations with PISA's Thematic Units along with physics students in initial teacher training, aiming to investigate the question: do PISA's thematic units in dialogical-problematizing and conceptual unifying perspectives make possible desirable changes in educational practice? Positive signs for the issue investigated suggest that connections between the concept of *Translator Dialogicity* and *Unifying Concepts* emerge from the teaching situations by teaching mediation in line with simulations or other *Open Educational Resources*.

Keywords
PISA, Structuring Themes of Physics Teaching, Unifying Concepts, Interactive Simulation

•Received 12 April 2016 • Revised 13 December 2017 • Accepted 15 April 2019

State of the literature
- Recent studies indicate advances and contributions of research in physics teaching connecting Brazilian educational guidelines and ENEM. Among the works that discuss this issue, we highlight the hypermedia study activities.
- Discussions in the scientific community and teacher training about PISA are incipient in Brazil.
- The development of study activities with PISA's thematic units and interactive simulations contribute to fill this gap, covering school practices based on interdisciplinary and contextual dimensions of knowledge in Natural Sciences and their Technologies.

Contribution of this paper to the literature
- This article contributes to the usage of open didactic approaches to PISA's contextualized and interdisciplinary thematic units with the support of digital information and communication technologies in dialogical-problematizing and conceptual unifying perspectives
- We relate the thematic unit "Climate Change" to Brazilian educational guidelines and unifying concepts in order to propose hypermedia study activities with interactive simulations in initial and continuing teacher training.
- We emphasize desirable consensual changes in the educational practice of physics teachers that undoubtedly include understanding and critical use of open educational resources.

Introduction
As new Brazilian educational plains and guidelines make progress, large-scale assessments as the National Standard Exam of High School (ENEM) and the Program for International Student Assessment (PISA) are becoming reference for High School and for courses of initial and continuing teacher training. In opposition to the simple training, the critical appropriation of these exams by students mediated by the teacher can result in cultural gains of the essential knowledge of Science and Technology (S&T) as citizenship instruments.

Recently, José, Angotti and de Bastos (2016) have stablished connections between knowledge, skills and abilities of PISA and the Structuring Themes of Physics Teaching (STPT), proposed in the Brazilian education guidelines (Brasil, 2002) through Unifying Concepts (UC): transformations, regularities, energy and scale. These include the mediation with free and open Digital Information and Communication Technologies (DICT) (Angotti, 2015).

The present study proposes the development of Hypermidiatic Study Activities (HSA) through interactive simulations with PISA's Thematic Units (TU) with physics students in initial teacher training. It is our objective to highlight the educational potential of PISA-STPT-UC connection in didactic approaches to openly solve problems in a unifying conceptual perspective.

We have experimented the proposal with the topic "Climate Change" in undergraduate classes in physics from the Universidade Federal de Santa Catarina (UFSC) and the Universidade Estadual do Sudoeste da Bahia (UESB) through a simulation that highlights the interaction of infrared photons with trace gases, available in the PHET website. Connections between the Translator Dialogicity concept and the Unifying Concepts emerging from the teaching-learning situations by teaching mediation in line with simulations or other Open Educational Resources (OER) as a central contribution for the teacher training.

Approach to Pisa's Physics Thematic Units through Hypermidiatic Study Activities
PISA's Science assessment is designed to measure, by sampling, the proficiency of students in the age group of 15 years of issues related to contexts/situations where "the elements of knowledge are interdependent or interdisciplinary" (Organization for Economic Co-operation and Development [OECD], 2013, p.17). Content, procedural and epistemological knowledge are assessed by examination taking into account the development of three competencies: evaluate

Copyright © 2017 Authors. Terms and conditions of Creative Commons Attribution 4.0 International (CC BY 4.0) apply.
https://doi.org/10.12973/ijpce/17113
* Corresponding author

and plan scientific experiments, scientifically explain phenomena and scientifically interpret data and evidence. Carvalho (2010) arguments that mental processes involved in addressing these issues, the knowledge required for these processes and the context/situation in which the processes and understandings are applied get close to the Brazilian educational guidelines. In fact, the PISA´s TU show conformity with the Science conceptions and about Science present in STPT (José, Angotti & de Bastos, 2016). These themes oppose to the compartmentalization of S&T knowledge in isolated contents, prioritizing the most essential/universal knowledge of physics and enabling an investigative view of the real world (Brazil, 2002).

Six STPT are proposed for the curricular organization of high school:

1- Movements: variations and conservations; 2- Heat, environment and energy uses; 3- Sound, image and information; 4- Electrical equipment and telecommunications; 5 - Matter and radiation; 6- Universe, Earth and Life. These themes unfold in units and subunits highlighting skills and abilities with different emphases and comprehensions. We have verified that the general training goals, learning objectives, training and structural axes established for the natural sciences and their technology areas in the National Curriculum Common Base (BNCC), in national discussion now, are included in the educational dimensions of the STPT.

In turn, the Unifying Concepts – transformations, regularities, energy and scale– connect curriculum and teaching. The study of the transformations of living/non-living matter and energy within space and time, the search for regularities and conservations, the framework of events/phenomena in a given scale are instruments of systematized knowledge in S&T, from the earliest times to frontiers achieved by men imbued with the relationship between process-product (Delizoicov, Angotti & Pernambuco, 2011).

In the curricular aspect, these four concepts play the role of breaking the barriers between disciplines or even traditionally sealed school contents, resignifying them. UC oppose the fragmentation of S&T knowledge, as they are considered supradisciplinary. In the scope of teaching, they work as "scientifically systematized knowledge glasses" in order to critically analyze problem situations of scientific and technological daily life. These, for example, can have as their starting and/or ending point the thematic units of Pisa worked educationally in the dynamic codification- problematization-decoding.

José, Braga, Nascimento and de Bastos (2014) and José, Angotti and de Bastos (2016) investigated the educative potential of STPT and UC, complementary to each other, in appropriation of ENEM and PISA assessments, respectively. The authors highlighted contributions to problematize the content-methodology pair in teacher training and essential aspects for the interdisciplinary and contextualized school work in the perspective of scientific and technological education.

In this perspective, de Bastos and José (2015) developed teaching situations connecting ENEM with STPT and UC in teacher training classes in physics at the Universidade Federal de Santa Maria and at the Universidade Estadual do Sudoeste da Bahia, with Moodle environment support. Their research results seem to emphasize the innovative character of the openly and collaborative problem solving of interdisciplinary and contextualized natural science issues of ENEM. However, they also revealed that there has been little possibility of creating similar activities during teacher training.

An analogous didactic strategy would be to implement PISA-STPT-UC connection in the physics teaching-learning process through Hypermidiatic Study Activity (HSA). In both situations, it is considered as a design matrix the Study Activity (SA) conception elaborated by Arruda (2003). It is directive, requires planning, implementation and evaluation, experimentation with the study material

Once defining the problem situation, an educational hypermedia (interactive simulation, for example), the corresponding STPT and relevant skills and abilities, it is examined the "step by step to be problematized with students, serving as a guide for interaction with hypermedia and the resolution of the problem situation" (Vidmar & de Bastos, 2015, p. 94).

The problematization is essential and opposed to the typical cake recipe, strongly criticized in science/physics teaching. The purpose is to provide conditions for the exercise of epistemological curiosity, being able to detach yourself from the object in order to return to it critically, to compare, to ask (FREIRE, 2004). The transformation of the statement of the thematic unit (usually composed of more than one question or item) is central because it is the teacher's duty to formulate the problems that the students do not formulate, implement pedagogically the Translator Dialogicity, established by Delizoicov, Angotti and Pernambuco (2011).

According to these authors, Translator Dialogicity (TD) consists of dialogue around a phenomenon or situation, in which the teacher apprehends students' world visions and conceptions (right or wrong) in order to emerge the contradictions present in their day-to-day lives, and gradually to teach about S&T.

> Now, if the purpose of the teaching of Science is the interpretation of the phenomenon or situation – object of study of Science - it is he who comes to dance. In choosing it as a starting point (which does not always occur), the educator-educator interaction becomes mediated by it and requires that "translation", which obviously can only happen if both issue the communication … (Delizoicov, 1991, p. 53)

"Climate Change" Hypermidiatic Study Activity through an Interactive Simulation

As an example, we present in **Table 1** a HSA elaborated from the PISA's thematic unit called "Climate Change" (OECD, 2006, p.22; Instituto Nacional de Estudos e PesquisasEducacionais "Anísio Teixeira" [INEP], 2011), which is contextualized and interdisciplinary, involves S&T thematic related to the production and use of energy and its effects on the environment, highlighted on a scale dimension. This thematic unit (in appendix) falls into two STPT (2- Heat, environment and energy uses; 5- Matter and radiation). The skills of those themes were associated by us with teaching objectives and are summarized as follows: 1. To recognize the different processes involving heat and their dynamics in weather events to assess the human intervention on the climate; 2. To verify the process of radiation interaction with material means in order to explain phenomena involved in emission and transmission of light.

The transformation of the statement of the TU "Climate Change" question is the first step toward the "translation" to what we refer. We seek to start open the dialogue in physics teaching using a language closer to the students' first culture, learn their worldview, sharpen contradictions and perceive knowledge gaps by the mediating the concrete (life experiences) and the theoretical (scientific and technological) contexts (Menezes, 1980; Delizoicov, 1983), making it possible through the problem-situation resulted from this encoding process.

Decoding occurs while performing the heuristic steps that we made to manipulate the interactive simulation "The Greenhouse Effect", on the "Photon Absorption" tab, as outlined in Table 1. The translator dialogue goes from descriptive to analytical, from the perspective of inverted symmetry, allowing the detachment of the epistemic subjects teacher and students of the problem-situation, in order to return to it critically, in a similar move to the Three Pedagogical Moments (Delizoicov, Angotti & Pernambuco, 2011). In the case of this heuristic, the unifying concepts themselves are exposed making clear their contribution to the phenomenological approach.

This process of encoding- problematization-decoding brings out two other important points. First, the heuristic resolution requires modern and contemporary physics knowledge concerning the interaction of radiation with matter. This is central in the current S&T context and whose inclusion in the classroom has been strongly defended in researches in physics teaching and in the curriculum guidelines.

The second point is that "Climate Change" is a controversial theme in constant discussion of potential indicators of global warming. Is this indeed caused by an anthropic effect in the emission of greenhouse gases or is it part of the Earth's evolutionary dynamics? How to measure the effects of aerosol particles as they are not completely known or yet, how measure the sharing of the effects of sea temperature or cosmic rays, etc. (Veiga, 2008)?

Table 1.: HSA "Climate Change"

Thematic	Crosscutting theme Environment, specifically, radiation interaction with greenhouse gas molecules.
Open Educational Resource	Interactive simulation "Greenhouse Effect" (tab Photon Absorption), available on the PHET website phet.colorado.edu/en/simulation/legacy/greenhouse (Copyright 2016 by University of Colorado Boulder.)
Goals	- To verify regularities observed in the simulated interaction of photons with trace gas molecules at microscopic level. - To analyze the effects/transformations in the atmosphere (macroscopic scale). - To highlight the radioactive balance (competition between driving forces) via energy conservation.
Definition of Study Activity actions	- Problem situation: Climate Change Thematic Unit (attached). - Transformation of the statement of the question: Considering that, the energy production and consumption cause climate and environmental changes such as the greenhouse effect, how to outline a human activity that minimizes these variations in the environment?
Definition of Study Activity operations	- Step 1: Select the top right tab "photon absorption." See in the right corner the atmospheric gases and in the left lower corner the options "infrared photon " and "visible photon". What are these photons and in which aspects do they differ? - Step 2: In the right table, select the "CH4" option and slide the center bar of the flashlight to the right, at first with the selection "infrared photon" and then with the selection "visible photon". What happens on a microscopic scale? - Step 3: Repeat the procedure for the N2 and O2 gases, which account for 99% of the atmospheric composition, and for the trace gases called CH4, CO2, H2O, writing the observed regularities down in a table. What can be affirmed about the absorption and emission of photons by molecules of these gases? - Step 4: Now, select the "Build Atmosphere" option and put a number of molecules for each gas, according to the atmospheric composition (the most present in greater numbers, without percentage correspondence between molecules). Then click in the "infrared photon" option and slide the center bar of the flashlight to the right. What happens in macroscopic scale? What transformations may occur in the atmosphere system in regard to energy? - Step 5: Considering that the atmosphere cooling caused by particles (aerosols such as SO2 gas, for example) could be the result of radiation reflected into space by more concentrated clouds (aerosols could act as condensation nuclei for water vapor droplets), what can be affirmed about the radioactive balance of the thermodynamic system Earth-atmosphere? - Step 6: Considering what you have observed in these five steps, solve the problem-situation referring to PISA's UT (in appendix)

The World Climate Conference (COP21) held in France at the end of 2015 refers mainly to the commitment to an environmentally sustainable global economic development. Out of options of carbon-free energy sources and subsidies to countries that need to develop and cannot hold responsibility for the most polluting countries, in the school context, the issue requires

contributions from all areas of knowledge to allow students to have understanding and positioning.

HSA "Climate Change" in Teaching Situations: Limits and Possibilities

We experimented the proposal through teaching situations in four groups of undergraduates in physics from the Universidade Federal de Santa Catarina (UFSC) and the Universidade Estadual do Sudoeste da Bahia (UESB), totaling 31 students, with a general workload of 4 class hours (only one class had a greater availability, 7 class hours). It was accepted, therefore, variation and flexibility in the didactic approach, comprising the presentation and problematization of PISA-STPT-UC connection and realization of HSA "Climate Change".

Our data, from audio records of classes held, show positive signs about the potential of the phenomenological discussion of the problem-situation mediated by the four unifying concepts: regularities evident in the interaction of infrared photons with trace gases molecules at the microscopic level; effects of this interaction/transformations in the atmosphere (macroscopic scale); analysis of radioactive balance by energy conservation. The UC guided the investigative look towards the scientific knowledge necessary for the codification-decoding process.

The students verified that the greenhouse effect is a consequence of transformations resulting from an energy balance phenomenon in the atmosphere. The so-called forcing, trace gases/aerosol, compete with each other for the heating/cooling of the atmosphere, contributing to variations between the total energy incident on the planet and the energy radiated into space, in accordance with the first law of thermodynamics. The second law, the principle of increasing entropy, indicates that the process is not reversible, potentializing environmental degradation. This translator dialogue is essential because it works as a bridge from what students already know about thermodynamics of equilibrium to the phenomenological understanding of the problem situation.

In the same way, it was problematized that the forcing theory appears together with other theories in a controversial scientific debate. As a summary, they perceived that the understanding of global warming is still an open and controversial topic of discussion among different research groups and global policies under constant political, economic, social and environmental interests.

It can be noted that more advanced classes (sixth semester) and students in supervised internship or already teaching classes in high schools showed larger depth of discussion and commented about the potential of activity.

An excerpt of the problematizing dialogue around the unifying concept scale in the phenomenological approach and interaction with the simulation (P: Teacher; U: Undergraduate) is presented as follows:

P: Does the idea of working with the concept of scale help?

U: It does here, because you are looking at the microscopic level... If you could change the scale of the simulator, then... and if you could go from micro to macro, I think that, for the student [of high school] and for us, it would become... a better idea. It would be radiation coming, part of it reflected and another part absorbed and the energy balance itself, how it will be changed over time.

P: but the analysis, this analysis we did, phenomenological... is it enough to understand the greenhouse effect?

U: Yes, it is enough.

P: Later, when you extrapolate it to a wider scale, and you have the possibility to talk to the student, only you can use another tab... If you use the first tab, you have the possibility to work... this aspect of the atmosphere... including over several eras... at least three... Then you have space transformations and time transformations... you can work other possibilities, History, Geography...

The dialogue excerpt above shows the importance of the "visualization" for understanding the interactive simulation. The undergraduate states that the high school student would have a larger opportunity to understand the transformations in the atmosphere at a macroscopic point of view. The teacher emphasizes that another tab could help in this case, too. As Gilbert (2005) points out, what is at stake is the development of a metavisualization, the way in which the student perceives and thinks about viewing in his mind and rearranges his knowledge in respect of a particular object or model, for example.

The reading of this excerpt leads us to infer that the unifying scale concept occupied a central place in the dialogue-translator developed in the HSA and also allowed us to dialogue around the apprehension and critical use of interactive simulation for physics teaching.

In order to prevent the formation of misconceptions associated with a corpuscular model of light, the following points are relevant in the approach of on-screen simulation with the students: 1- colors for the photons have illustrative purpose (infrared photons are not visible to the naked eye, they are not red); 2- molecules, photons and proportion of trace gases in the atmosphere are represented pictorially; 3- photons are not the same as balls propagating in space. In short, the view and the approach of a simulation can be discussed using general aspects of Didactic Transposition (Chevallard, 2005) and Computer Transposition (Balacheff, 1993) around representations, models and theories.

In addition, animations, simulations and dynamic media, among other potential resources to stimulate interest and involvement of the students do not result in knowledge gains for students if specific guidelines are not explicit in conjunction with the objective of such an initiative (Vavra et al., 2011).

Physicists in initial teaching training understood the concept of Einstein's quantum of energy (which introduces the idea of the dual nature of light in the quantum paradigm) or the contribution of the radioactive energy balance for global warming (considering the first and

second laws of thermodynamic) through specific actions and procedures of the heuristic developed. It was configured as propositional to verify the role of unifying concepts in the construction of knowledge, its values and philosophies.

However, it was not possible to see whether they actually grasped the PISA-STPT-UC-ICDT connection. We believe that if they exercise the implemented proposal planning themselves a similar teaching situation or even developing it into a supervised internship activity they may take the desired qualitative leap.

In less punctual interventions set in larger depth and breadth along a discipline or course, we can discuss the epistemic and dialectical character of the pair rupture-continuity, the relationship process-product, the tension between professional training and professional practice, with possible outcomes favorable to the use of the on-screen understanding proposal in other situations and contexts.

Final Considerations

Have national and international assessments of school learning diagnosed and signaled innovations needed to curricula? (José et al., 2014; José & Angotti, 2016). To the extent that they become paradigmatic and present themselves as regulatory and control mechanisms, are PISA and ENEM seen as a simple proposal to reduce school curricula to mere preparatory mechanisms? If so, this is an answer that, joined with the nature and proposition of these tests, must be tensioned in initial and continuing teacher training. Could intentionally taking ownership of these tests against the dogmatism path result in cultural gains as citizenship instruments and access to social goods of transformative potential (Vilches & Gil-Pérez, 2010)? After all, scientific and technological education is intended for everyone, isn't it? (American Association For The Advancement of Science [AAAS], 1989).

Positive signs for the issue we investigated suggest that connections between PISA and Brazilian curriculum guidelines parameterized by unifying concepts favor the approach of the triad curriculum-evaluation-teacher training. Martins (2015) considers the problematization of this triad as necessary to include consensual and diverse themes on the nature of science in education, in an open, investigative and dialogical perspective among disciplines. Broad themes, compatible with the Brazilian scientific and technological context, are able to identify socio-historical contradictions with different intensities in different regions (Angotti, 1993, 2015).

Our analysis allows us to conclude that these themes gain significance for the teaching practice of translator dialog city enabling the transformation of the statement of questions in exams such as PISA and ENEM, among others, into problem-situations of the scientific and technological daily lives of educational subjects, in the language of their prevalent knowledge (first culture), so we can dialogue around them. Conflicts with the elaborate culture, (Angotti, 1993), analysis and synthesis guided by unifying concepts allow us to "perceive the truly epistemological differences between scientific and everyday knowledge" (Martins, 2009, p. 276) in the development of the teaching-learning process.

The unifying concepts can facilitate and strengthen dialogue, problematization and communication between epistemic subjects, teacher and students, avoiding dispersions and excessive fragmentation of knowledge. With support of DICT the process can be richer and deeper, more collaborative and flexible among disciplinary content, its contextual dimensions and interdisciplinary and cross relations (Angotti, 2015). Hence the importance of the teacher, who has universally systematized knowledge of S&T, to move between the two cultures.

The example that we shared herein presents problems/situations that characterize the synchronic aspect of training and provide opportunities for the resolution by similarity of other problem-situations that may be solved by undergraduates, characterizing the diachronic aspect of the training. The development of this HSA can contribute to some curricular transversality or, at least, to integration between disciplines.

We emphasize that the quality and intensity of the translator dialogue is needed in different spaces and times. HSA with mid-level learners require more contour and focus on the phenomenological discussion made possible by interactive simulation. Spaces of initial and continuing teacher training assume larger abstraction and discussion of pedagogical, scientific and technological knowledge with a degree of depth to be negotiated with the actors, taking into account the time available.

Acknowledgements

One of us (Wagner D. José) thanks the Universidade Estadual do Sudoeste da Bahia and the Universidade Federal de Santa Catarina for their support.

References

AAAS - American Association for the Advancement of Science (1989). *Science for All Americans: Project 2061*. Oxford University Press. Retrieved August 25, 2015 from www.project2061.org/publications/sfaa/online/sfaatoc.htm.

Angotti, J. A. P. (1993). Conceitos unificadores e ensino de Física. *Revista Brasileira de Ensino de Física, 15*(1-4), 191–198.

Angotti, J. A. P. (2015). Ensino de Física com TDIC. Florianópolis: UFSC/EAD/CFM/CED. Retrieved February 04, 2016 from ppgect.ufsc.br/files/2016/01/Ensino_FSC_TDIC_1215.pdf.

Arruda, J. R. C. (2003). Un Modelo Didáctico para Enseñanza Aprendizaje de la Física. *Revista Brasileira de Ensino de Física, 25*(1), 86-104.

Balacheff, N. (1993). Artificial Intelligence and Mathematics Education. (1993). In: 14th Biennal of the AAMT. Perth, Australia, Retrieved February 04, 2016 from hal.archives-ouvertes.fr/hal-00190342/document.

Brasil. Ministério da Educação. Secretaria de Ensino Médio e Tecnológico. (2002). *PCN+ Ensino Médio: orientações educacionais complementares aos Parâmetros Curriculares Nacionais. Ciências da Natureza, Matemática e suas Tecnologias*. Brasília: MEC/SEMTEC.

Carvalho, A. M. P. (2010). Formação e prática profissional de professores de Física. In N. M. Garcia, I. Higa, E. Zimmermann, C. C. Silva, & A. F. P. Martins (Eds.), *A pesquisa em ensino de física e a sala de aula: articulações necessárias*. São Paulo: SBF.

Chevalard, Y. (2005). *La transposición didáctica: del saber sabio al saber enseñado*. Buenos Aires: Aique Grupo Editor.

De Bastos, F. P., & José, W. D. (2015). *Trabalho Interdisciplinar com Questões do Enem em Ambientes Hipermidiáticos. In Scientific Communication Annals, 7th Congresso Nacional de Ambientes Hipermidiáticos para Aprendizagem*. São Luís: Universidade Federal do Maranhão.

Delizoicov, D. (1983). O ensino de física e a concepção freireana da educação. *Revista Brasileira de Ensino de Física, 5*(2), 85-98.

Delizoicov, D. (1991). *Conhecimento: tensões e transições (Tese de doutorado). Faculdade de Educação*. São Paulo: Universidade de São Paulo.

Delizoicov, D., Angotti, J. A. P., & Pernambuco, M. M. (2011). *Ensino de Ciências: fundamentos e métodos* (4rd Ed.). São Paulo: Cortez.

Freire, P. (2004). *Pedagogia da Autonomia* (30rd Ed.). Rio de Janeiro: Paz e Terra.

Gilbert, J. K. (2005). Visualization: A Metacognitive Skill in Science and Science Education. In Gilbert, J. K. (Org.). Visualization in Science Education. Holanda: Springer, p. 9-27.

José, W. D., Braga, G. R., Nascimento, A. Q. B., & De Bastos, F. P. (2014). ENEM, Temas Estruturadores e Conceitos Unificadores no ensino de Física. *Ensaio: Pesquisa em Educação em Ciências, 16*, 171-188.

José, W. D., Angotti, J. A. P., & De Bastos, F. P. (2016) Ensino de física por meio de questões do PISA associadas a Temas Estruturadores e Conceitos Unificadores. *Caderno Brasileiro de Ensino de Física, 33*, 333-354.

Martins, A. F. (2009). Sobre rupturas (e continuidades...). In A. F. Martins (Ed.), *Física ainda é cultura?*. São Paulo: Ed. Livraria da Física.

Martins, A. F. (2015). Natureza da Ciência no ensino de ciências: uma proposta baseada em "temas" e "questões". *Caderno Brasileiro de Ensino de Física, 32*, 703-737.

Menezes, L. C. (1980) Novo(?) Método(?) para Ensinar(?) Física(?). Revista Brasileira de Ensino de Física, 2(2), 89-97.

Organisation for Economic Co-operation and Development. (2006). *PISA Released Items – Science*. Retrieved May 15, 2016 from www.oecd.org/pisa/38709385.pdf.

Organisation for Economic Co-operation and Development. (2013). *PISA 2015: Draft science framework*. Retrieved September,15,2015, from www.oecd.org/pisa/pisaproducts/Draft%20PISA%202015%20Science%20Framework%20.pdf.

Instituto Nacional de Estudos e Pesquisas Educacionais "Anísio Teixeira" (2011). *Programa da OCDE para Avaliação Internacional de Alunos – PISA: Itens Liberados de Ciências*. Retrieved June 20, 2015 from http://download.inep.gov.br/download/internacional/pisa/Itens_liberados_Ciencias.pdf.

Vavra, K. L., Janjic-Watrich, V., Loerke, K., Phillips, L. M., Norris, S. P., & Macnab, J. (2011). Visualization in science education. *Alberta Science Education Journal, 41*(1), 22-30.

Veiga, J. E. (Org.). (2008). *Aquecimento Global: frias contendas científicas*. São Paulo: Editora SENAC.

Vidmar, M. P., & De Bastos, F. P. (2015). Ensino de física, hipermídia e ambiente em rede. Santa Maria: UFSM/LAPEDOC, Retrieved March 13, 2016 from laveala.proj.ufsm.br/pluginfile.php/2743/mod_resource/content/2/Ebook_Ensino_de_Fisica_Hipermidia_e_Ambiente_em_Rede.pdf.

Vilches, A., & Gil-Pérez, D. (2010) El programa Pisa: un instrumento para la mejora del proceso de enseñanza-aprendizaje. *Revista Ibero-Americana de Educação, 53*, 121-154.

Appendix

Climate Change Text 1 (OECD, 2006, p. 22)

Read the following information and answer the questions which follow.

WHAT HUMAN ACTIVITIES CONTRIBUTE TO CLIMATE CHANGE?

The burning of coal, oil and natural gas, as well as deforestation and various agricultural and industrial practices, are altering the composition of the atmosphere and contributing to climate change. These human activities have led to increased concentrations of particles and greenhouse gases in the atmosphere. The relative importance of the main contributors to temperature change is shown in Figure 1. Increased concentrations of carbon dioxide and methane have a heating effect. Increased concentrations of particles have a cooling effect in two ways, labelled 'Particles' and 'Particle effects on clouds'.

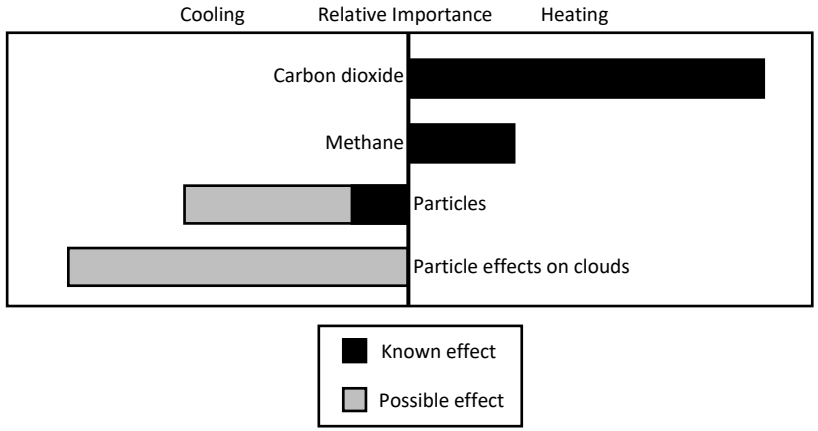

Figure 1. Relative importance of the main contributors to change in temperature of the atmosphere.

Bars extending to the right of the center line indicate a heating effect. Bars extending to the left of the center line indicate a cooling effect. The relative effect of 'Particles' and 'Particle effects on clouds' are quite uncertain: in each case the possible effect is somewhere in the range shown by the light grey bar.

Source: adapted from http://www.gcrio.org/ipcc/qa/04.html

Question 1: CLIMATE CHANGE S210Q01- 0 1 2 8 9

Use the information in Figure 1 to develop an argument in support of reducing the emission of carbon dioxide from the human activities mentioned.