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Socioscientific Argumentation and Model-Based Reasoning: A Study on Mining Exploitation in Colombia*

La argumentación sociocientífica y el razonamiento basado en modelos: Un estudio sobre la explotación minera en Colombia

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Mario Fernando Gutiérrez R. [a]
Pontificia Universidad Javeriana, Colombia
ORCID: http://orcid.org/0000-0003-3452-8658

ABSTRACT

The primary objective of this article is to identify the mental models that represent a social-scientific problematic specific to high-school Colombian students. This is followed by the analysis of the argumentative schemes that these students may use to justify such models. By using a combined design, fifty two participants (52 people, 31 women and 21 men between the ages of 15 and 23; with education levels between high school and undergraduate degree) analyzed the possibility of implementing a mining exploitation project in a specific region of Colombia that is currently under the administrative control of one of Colombia's native communities. The qualitative analysis showed the presence of 11 models for thinking about the given social-scientific problematic and a limited range of argumentation schemes (11); the quantitative analysis through ANOVAs (variance analysis) showed significant differences regarding the number of arguments per grade and the mental model. The results are discussed emphasizing the advantage that proceeds from exploring the students' argumentative speech from a developmental-cognitive perspective with significant implications in the educational field.

Keywords

Socioscientific issues; socioscientific argumentation; model-based reasoning; argumentation schemes; student beliefs.

RESUMEN

En el presente artículo se tiene como objetivos identificar los modelos mentales que representan una problemática sociocientífica específica para estudiantes colombianos en secundaria y analizar los esquemas argumentales que implementan para justificarlos. Utilizando un diseño mixto, cincuenta y dos participantes (52 personas, 31 mujeres y 21 hombres con edades entre los 15 y los 23 años de edad; en niveles escolares de secundaria y pregrado) analizaron la posibilidad de implementar un proyecto de explotación minera en una región bajo control administrativo de una comunidad indígena colombiana. Los análisis cualitativos dan cuenta de la presencia de 11 modelos para pensar la problemática sociocientífica propuesta y un rango limitado de esquemas argumentales (11); los análisis cuantitativos a través de ANOVAs dan cuenta de diferencias significativas para la media de argumentos por grado y modelo mental. Se discuten los resultados resaltando lo conveniente que resulta

a Correspondence author. E-mail: mariogutierrez@javeriana.edu.co

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explorar el discurso argumental de estudiantes desde una perspectiva cognitiva y desarrollista con importantes implicaciones para el ámbito educativo.

Palabras clave
Problemáticas sociocientíficas; argumentación socio-científica; razonamiento basado en modelos; esquemas argumentativos; creencias de estudiantes.

This paper addresses the argumentative speech of Colombian secondary school students when discussing a socio-scientific issue. By analyzing their discursive performance, we attempt to point out the different linguistic resources these students use when analyzing a real situation that affects specific populations. As such, this proposal is unlike the traditional exploration of students' argumentative skills from a normative perspective (Toulmin, 1993), when they analyze situations outside their experience and socio-cultural context (Kuhn, 2015), and instead places itself within the framework of metacognitive textual work (Myhill & Jones, 2015). This framework assumes the existence of specific representations of the topic under discussion, that guide or model its understanding. The analysis of socio-scientific issues from a model-based perspective involves two additional conceptual axes: argumentation, and model-based reasoning theory.

The publication of works by Perelman & Olbrechts-Tyteca (1958) and Toulmin (1993) helped create a new starting point for the study of argumentation, which has become even more complex with the addition of cognitive (Kuhn, 1991; 2005; Kuhn, Iordanou, Pease & Wirkala, 2008), interactional (Doury, Quet & Tseronis, 2015; Kerbatch-Orecchioni, 1992; Traverso, 1999), and polemic components (van Eemeren, Houtlosser & Snoeck, 2007), including the image of the Self in discourse (Amossy, 2006, 2014, 2016) or the role of emotion in argumentative discourse (Plantin, 2011, 2015), amongst others.

The argumentation is defined as a rational activity which tries to provide a good reason that will make someone admit a given conclusion (Plantin, 2014); this is done using language, and the activity is directed towards an interlocutor. Argumentation is a discursive activity which holds reasoning; it is, therefore, a cognitive and epistemic activity linked to demonstration, which is developed in more formal languages. Argumentation is a discursive process that attempts to solve or prevent a difference in opinion, highlighting the acceptability of a point of view that is doubted (van Eemeren, et al., 2014).

The argumentation of socio-scientific issues is amongst the newest developments in argumentation. The expression "socio-scientific issue" defines controversial concepts or social themes that have conceptual, procedural, and technological links to science (Sadler & Donnelly, 2006; Herman, Sadler, Zeidler, & Newton, 2018). Current socio-scientific issues comprise, amongst others, biotechnology and the environment, genetic engineering, cloning, local pollution issues, and global climate change. From Fowler, Zeidler and Sadler (2009), socio-scientific argumentation involves the skill to negotiate and make decisions related to social issues that, to be wholly understood, require using scientific and moral concepts. Their work has shown that socio-scientific argumentation promotes significant moral reflection on society (Fowler, Zeidler & Sadler, 2009).

Studies of argumentation have shown that promoting discussions through socio-scientific issues significantly increases the understanding of specific contents in biotechnology (Sadler, Romine & Topçu, 2016), improves comprehension of science influencing decision-making (Jho, Yoon & Kim, 2014), and helps teachers progress from knowledge transmission to the promotion of higher-order cognitive processes in their students (Pitiporntapin, Yutakom, Sadler & Hines, 2018). Argumentation can also transform an exploratory discussion into communication amongst authentic interlocutors, thereby gaining social and individual relevance (Åkerblom & Lindahl, 2017), and facilitates student engagement in reading activities, where asking questions about a scientific discussion may make sense (Lederman, Antink & Bartos, 2014).

The educational and discursive usefulness of socio-scientific argumentation is fundamental.

Advocates of using socio-scientific issues, such as Klosterman and Sadler (2010), have stated that contextualizing the learning of social and natural sciences in the real world, fosters scientific discourse and helps create a well-informed mass of citizens that can actively participate in the solution of societal problems. When teachers use socio-scientific issues in the classroom, they stimulate their students and help them get involved in the development and assessment of arguments about challenging issues of public importance (Owens, Sadler & Zeidler, 2017).

The hypothesis guiding this report is that reflecting on socio-scientific issues might be framed inside model-based reasoning, since these models, given their possibilities, potential and restrictions, could promote the use of certain argumentative schemas, and restrict the use of others. The word models has different uses for Williams and Clement (2005), but in the context of this study, a model is, in a broad sense, a simplified representation of a system, which focuses on specific aspects of the said system. For them, the discussion around a model or the creation of one promotes the implementation of a set of specific cognitive strategies, directed towards promoting the discourse and fostering conceptual understanding. Gilbert (2011) proposes that models support explanation and understanding by simulating the structure and behavior of specific systems. These definitions focus on the qualitative aspects of comprehension since they emphasize getting students to create mental representations of the phenomena that can occur in a complex system (social or physical).

The creation and use of models can be analyzed in terms of four different tasks: construction, usage, assessment, and review (Schwarz et al., 2009; cited by Quillin & Thomas, 2015). In order to succeed in elaborating models, students must not only be able to create a model, but also to apply them to problem-solving or prediction, evaluating their efficacy and modifying steps if needed. Develaki (2017) points out that model-based reasoning, in this perspective, is a cognitive activity within scientific reasoning; to Develaki, scientific reasoning is a continuous, multidimensional activity that comprises a number of specific reasoning strategies, as well as specific types of arguments that scientists have developed to justify the creation of scientific knowledge and to confirm its validity.

A large part of the research on argumentation in scientific contexts or scientific training has focused on how to improve the argumentative skills of students (Adúriz-Bravo, 2011; Böttcher & Meisert, 2011; Kathpalia & See, 2016; Tsai, 2015). Studies on argumentative discourses and model-based reasoning are scarce; findings suggest that most students do not express uncertainty in the explanations or justifications they give for their models. The effect is increased when the task includes noisy data (Buck, Lee & Flores, 2014), or promotes important conceptual advances to understand a hydrological phenomenon, but with large variations amongst classrooms if a central curriculum does not integrate the activities (Zangori, Vo, Forbes & Schwarz, 2017), or the complexity of the model that guides the reasoning of students and the cognitive demand of the task are related to the type of tests included in their arguments (Moon, Stanford, Cole & Towns, 2017). These research results are valuable since they provide an understanding on how science instruction can drift away from a traditional, teacher-centric approach towards a student-centric approach that regards them as active participants of their own learning.

In this paper, the goals are to analyze the argumentative schemas implemented by Colombian secondary school students when discussing socio-scientific issues, to identify the models that represent the proposed socio-scientific issue, and to determine their relationship. A comparison of the different models which base the students' decisions is essential because the ability to communicate, negotiate, and apply agreements is a vital need in our western democratic societies. Analyzing the foundations of these decisions in detail can provide an idea of how these young or future citizens analyze Colombian issues and how they come up with solutions

Method

Type of study

This study was carried out with a cuasi-experimental design. We intended to identify the relation between argumentative schemas displayed by Colombian students when they discuss a socio-scientific issue and its underlying models.

Participants

We selected a non-probabilistic, convenience sample in a single school. Participants were 52 students (31 females and 21 males) aged 15-23 (M = 16.75, SD = 1.78), from grades 9th to college-aged. Participation was voluntary, and subjects signed an informed consent prepared according to the guidelines in Resolution 8430 / 1993 of the Colombian Ministry of Health and Social Protection (scientific, technical and managerial guidelines for health research). The project was subject to an ethical review and approved by the ICAR Group at Université Lumière (Lyon 2 – France). Table 1 shows the composition of the sample.

Table 1
Sample composition

Educational level	*N*	Average age
College	13	19.5
Grade 11	13	17.3
Grade 10	13	16.4
Grade 9	13	15.2

Analyzed social situation and interview protocol

A specially crafted text was given to participants. The text presented three reasons for and three reasons against oil exploration and extraction in Colombia, simultaneously describing the fight of the U'wa indigenous tribe to stop that type of project in their territory, despite the evident financial benefits derived from oil export. The text then asked the question "Should the extraction of oil in the U'wa territories be allowed, despite the repeated refusal by the community to approve any mining activity?"

Categories of analysis

All answers were transcribed in their entirety and the corpus was then analyzed in stages. In the first, individual stage, the principal researcher and two master's level, properly trained research assistants, analyzed the answers to inductively identify common patterns that could point to the existence of a *stable model*. Then, a group stage proceeded where models were compared to determine their potential ability to group information, therefore creating explanatory models with better heuristic strength.

In the second phase, the PI and the research assistants analyzed the interviews in groups in order to identify the types of arguments used by participants. For this, we employed Walton's (Macagno & Walton, 2015; Walton & Macagno, 2016) concept of argumentation schema; this concept refers to an organized, systematic resource that can be used to think about the different ways in which reasoning addresses an issue and about the final structure of the arguments used to discuss it. According to Walton, argumentation schemas are argumentative forms, or inference structures, that represent the most common types of reasoning in daily discourse, in judicial and scientific contexts (Walton, Reed & Macagno, 2009). Argumentation schemas can be classified according to the nature of their conclusion (Macagno & Walton, 2015); this allows for the representation of both daily and scientific reasoning, which in turn makes them appropriate for analyzing arguments in a socio-scientific discussion.

To determine the reliability of the observations made by the three people in charge of the analysis we calculated Cohen's Kappa coefficients; a

Kappa in the range 0.41 – 0.60 is mediocre; 0.61 – 0.80 good; and 0.81 to 1.00 is very good (Landis & Koch, 1977). The coefficients for the eleven identified models were between 0.61 and 0.80 (Table 2).

Results

After analyzing the answers, 11 specific models were identified that showed how participants reasoned about oil extraction at the U'wa territories (Table 2). Most students openly reject approving the project; we found a predominant trend in their reasoning from considering the issue from an economic standpoint (lower educational levels) to discussing exploitation as an activity that goes against consolidation and preservation of indigenous Colombian culture (higher educational levels).

At the higher grades, students demand that the administrative autonomy of indigenous communities, as ordered by Colombian law, be upheld. The idea of general financial benefit that oil exports would bring to the country is not considered or analyzed by participants. For students, exploration and exploitation of oil would be a sort of treason to the agreements made with native communities.

Table 2

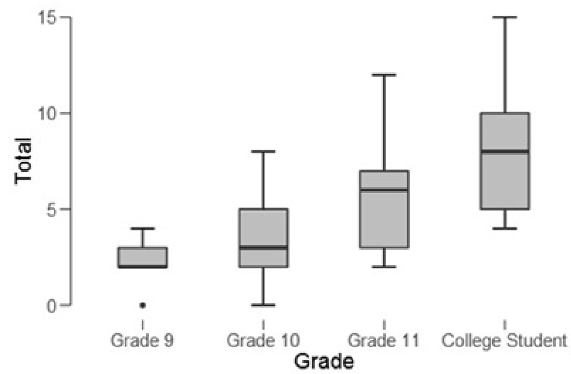
Model, average, standard deviation, Kappa coefficient and model definition

	Model	M, SD, Kappa	Model definition
M1	The power of multinational enterprises and the helplessness of peasants.	$M = 1.68$ $SD = 1.41$ $k = 0.61$	From a perspective based mainly on fair trade, this model proposes that the dialogue between oil companies and the indigenous communities is unfair, due to their asymmetric power relationship.
M2	The disappearance of agricultural production.	$M = 1.46$ $SD = 0.99$ $k = 0.65$	The oil infrastructure would endanger indigenous agricultural production. Traditional forms of agriculture would be affected by the machinery needed to drill and extract oil.
M3	The lack of an object of value for indigenous communities.	$M = 0.07$ $SD = 0.26$ $k = 0.68$	From the point of view of market analysis, the financial benefits to the communities may not be qualitatively valued by them. The financial compensation for oil drilling could not be valuable enough to support a negotiation.
M4	The acknowledgement of indigenous communities' authority.	$M = 0.09$ $SD = 0.30$ $k = 0.73$	The National Constitution of Colombia and the country's law are invoked to demand respect for the administrative autonomy of the indigenous communities. The rights communities have to make their own decisions related to their territories are to be respected.
M5	The corruption of State workers in Colombia.	$M = 1.20$ $SD = 0.63$ $k = 0.81$	Negative assessment of the ethical exercise of public service by state employees. This lack of ethical guidance would lead to the loss of financial benefits derived from oil exports due to corruption; the money would therefore not get to the indigenous communities and the exports would, therefore, be meaningless.
M6	The collateral damage to natural resources.	$M = 2.58$ $SD = 2.12$ $k = 0.61$	The oil industry would necessarily have a negative impact on natural resources and the region inhabited by indigenous communities. The damage could be intentional or not, but it would affect native flora and fauna indiscriminately.
M7	The inability of the indigenous population to adapt to the demands of urban life.	$M = 1.42$ $SD = 0.78$ $k = 0.62$	Assumes that the inclusion of indigenous communities in urban production systems is practically impossible. The educational difference with urban-raised people would prevent natives from integrating into urban productive life. The model highlights the knowledge of indigenous communities on farming and husbandry, but also the irrelevance of that knowledge to urban and industrial contexts.
M8	The defense of civil and human rights.	$M = 1.51$ $SD = 1.12$ $k = 0.70$	Human and constitutional rights are said to be violated by allowing mineral extraction. Personal interests of those in power affect the lives and dignities of indigenous communities. The difference with M4 is that this model does not address administrative, but fundamental rights.
M9	The development of clean, renewable technologies.	$M = 1.18$ $SD = 0.69$ $k = 0.91$	Dependence on fossil fuels needs to stop because they are not renewable, and it is urgent to develop technological replacements for oil. There is a proposal to transition to renewable energies.
M10	The protection and preservation of the environment, following the symbiotic balance that indigenous communities enter with their environment.	$M = 1.20$ $SD = 0.69$ $k = 0.65$	This model highlights the symbiotic relationship established between the indigenous communities and their natural environment. It proposes a reflection about how indigenous communities function and exist; the native lives in perfect communion with nature and not regarded as a contributing factor to environmental damage.
M11	The preservation of ancestral beliefs of Colombian indigenous communities.	$M = 1.33$ $SD = 0.49$ $k = 0.82$	The model suggests that Colombian cultural diversity would be put at risk and that it is urgent to protect and preserve it. The preservation of these cultures is a cultural imperative due to their belonging to the immaterial cultural heritage of Latin America. This heritage is regarded as being at risk due to economic and cultural domination.

From the argumentative point of view, a total of 259 arguments were extracted. The descriptives for arguments by participant and educational level (Figure 1) were as follows: 2.38 in Grade 9 (M= 2.38; *SD*= 1.32), 3.5 in Grade 10 (M= 3.53; *SD* = 2.26), 6.1 in Grade 11 (M= 6.11; *SD*= 3.43) and 8 for first year college students (M= 8.0; *SD* = 3.37). We conducted an analysis of variance (ANOVA) and confirmed significant differences in argument averages according to educational level $F(11.47) = 87.25$, $p < 0.001$ and model $F(2.84) = 3.73$ $p < 0.005$.

Figure 1

Arguments by educational level



The arguments were classified in 11 specific argumentative schemas according to Walton and Macagno (2016) – they are presented in Table 3.

Table 3
Argumentative schemes, averages, standard deviations, Kappa coefficients and schema definition

	Argumentative schema	M, SD, Kappa	Definition
SCH1	Argument through consequence	$M = 1.81$ $SD = 1.51$ $k = 0.68$	The premise of this schema is a presumably predictably consequence of an action; the conclusion is derived from whether the consequences are positive or not.
SCH2	Argument through cost-benefit relations	$M = 1.00$ $SD = 0.52$ $k = 0.80$	Through the cost-benefit argument, two or more options are compared under a fundamental principle; at the end, the option that provides the highest earnings and the least amount of losses should be chosen.
SCH3	Emotional argument	$M = 1.09$ $SD = 0.30$ $k = 0.67$	The emotions that could be elicited by an action or an event are used to support a decision. Emotions can be argumentative since they can be used to justify a point of view; they would be legitimate reasons.
SCH4	Argument through analogy	$M = 1.07$ $SD = 0.26$ $k = 0.73$	Two objects or object systems are compared, and this comparison highlights aspects that are thought to be similar; it is an explicit representation of the similarities between the two to support a conclusion
SCH5	Argument through values	$M = 1.18$ $SD = 0.60$ $k = 0.75$	In this schema, an action or decision is judged by an agent A as negative (called -V). This negative value spreads to the final goal to be reached by executing this action, and the action or decision is therefore rejected.
SCH6	Argument from evidence to hypothesis	$M = 2.60$ $SD = 2.58$ $k = 0.80$	This schema states that if *A* (a hypothesis) as true, then *B* (a proposition reporting an event) will be observed to be true. When *B* is observed to be true, in a given instance, A must necessarily be true as well.
SCH7	Argument from a random sample to a population	$M = 1.81$ $SD = 1.32$ $k = 0.89$	From the observation of several instances of the co-existence of two properties, a generalization is concluded.
SCH8	Causal argumentation	$M = 1.63$ $SD = 1.21$ $k = 0.86$	In causal argumentation, a justified statement regarding a fact or phenomenon and its explanation is advanced, which results in a generally verifiable hypothesis.
SCH9	Practical inference	$M = 1.36$ $SD = 0.67$ $k = 0.84$	According to this schema, if a goal G involves carrying out action A, then action A must be performed.
SCH10	Example-based argument	$M = 1.16$ $SD = 0.70$ $k = 0.83$	This schema features the existence of a particular case, with properties X and Y. If the other case has property X, then it must have property Y as well.
SCH11	Argument from popular opinion	$M = 1.29.$ $SD = 0.46$ $k = 0.91$	This fallacious schema is based on stating that generally accepted statements must be true, and statements that are generally rejected must be false. A subtype of this schema is that if the members of a certain group accept or reject something, then it must be true or false, accordingly.

Discussion

When participants discuss socio-scientific issues, they seem to need to set forth specific solutions based on the practical knowledge they have of their social context. These solutions are framed within and restricted by, the variables that affect the issue under review. Therefore, certain cognitive and discursive frames are more salient in the participants' reasoning, to coherently integrate knowledge, emotions, and beliefs about the social or natural phenomenon they are analyzing. As such, this type of task requires the problem-solver to create a mental model to integrate the variables that will explain the phenomenon under study, whilst implementing several argumentative schemas at the same time.

A model is a simplified abstraction that represents a particular phenomenon and can consist of both external and mental representations (Crawford & Jordan, 2013). In contrast to more traditional conceptions of model-based reasoning, which consider it to be the visual representation of a phenomenon (Hay & Pitchford, 2016; Kragten, Admiraal, & Rijlaarsdam, 2015; Quillin & Thomas, 2015), this study found evidence to state that these models are identifiable when socio-scientific issues related to mining are discussed. These models allow for a global understanding of the situation and a set of actions leading to the proposed goal. Recent literature about this same hypothesis shows that this research topic also facilitates the combination of collective negotiation processes and iterative, external, individual representations of a problem (Pennington et al., 2016).

With this representation, one can have an idea of plausible actions when faced with the dilemma of extracting oil and export it for economic gain, but also having a negative impact on the environment and the native communities settled in the regions where oil extraction takes place. Influential dual process models of human thinking posit that reasoners typically produce a fast, intuitive heuristic (i.e., Type-1) response which might subsequently be overridden and corrected by slower, deliberative processing (i.e., Type-2). However, and in the same vein as other recent studies (Bago & De Neys, 2017; Stephens, Dunn & Hayes, 2018), it seems that decisions made regarding socio-scientific issues are based on viable facts and data, with high reliability from the beginning of the discussion. Arguments would be directed towards sharing and justifying the decisions, which would be supported by the underlying mental model.

Decisions in a problem-solving situation are made in a dual-space: before (prediction of the result) and after the decision (analysis of the real results of the prediction); hence, decision-making involves considering multiple scenarios pre and post (Meyer, 2018). This study aims to enhance Meyer's proposal for decision making by including the schematic representation of the situation (mental model) in the pre-phase, and the selection of an appropriate justification of the decision (argumentation schema). Models organize thought and function as tools for communication, since they allow individuals to create visible constructions of implicit constructs, whilst helping participants in the process of modeling, and understanding their object of analysis (Sorensen, et al., 2016). This research is showing the election of an argumentative schema as an inferential achievement of the participants, and it is deemed needed as part of a problem-solving situation since the inferential structure of these schemas has a close relationship with the scientific domain that circumscribes the decision and the model.

As such, when the knowledge domain containing the phenomenon under discussion is identified, explicitly or implicitly, there would be a need to adapt discourse to this domain to reach validity and authenticity through the increase in its social and individual importance. The analysis of variables affecting human reasoning in situations of chance games, or economic expectation analysis, or investment decisions, has shown that the way people weigh options in a decision-making situation, or the way they persuade others to decide, reflects their reasoning (Lee, Koh, Cai, & Quek, 2012; Koh, 2016). Therefore, analyzing how decisions are justified requires identifying the models that underlie argumentative discourse.

The identified mental models make it possible to glimpse the understanding students have about the problem under discussion, since they contain information about mining, possible consequences on the environment, and about the native communities inhabiting the affected regions. However, their statements have different degrees of validity, because they can go from very personal beliefs to data and facts. No evidence was found of metacognitive monitoring in their reasoning to discuss the pertinence of the sources of information they base their knowledge on.

Argumentation schemas reflect the students' reasoning and have an inferential link to the models built by the students when analyzing a problem. Causality is inherently subjective because the speaker actively thinks about a conclusion on the basis of observation here and now; hence, causal models are also subjective, and discourse is their channel of expression (Sanders & Spooren, 2015). Model-based reasoning validates, inferentially, both the decisions that need to be made, and the ways those decisions should be justified and defended, under the same mental process.

Given the diversity of mental schemas identified by Walton, it is remarkable that only eleven of them were identified here. Walton grouped these eleven schemas into the practical and causal reasoning categories, which highlights the use of schemas related to scientific reasoning in STEM education. Literature about the subject has emphasized that students need to have significant challenges involving authentic topics of relevance to their lives; the construction of scientific knowledge and the generation of meaning emerge as they participate increasingly in the discussion of scientific topics (Smyrnaiou, Petropoulou & Sotiriou, 2015; Trouche, Sander, E. & Mercier, 2014). As such, the discussion on the exploitation of oil resources evokes particular ways of discussion, that in turn elicit resources about scientific reasoning.

The students build their arguments in two different ways. First, they used pronominal words to minimize the difference in power between themselves and a more powerful agent; second, they used scientific terms to gain the upper hand over the more powerful agent (Åkerblom & Lindahl, 2017). In this study, we found the same strategies, although with a subtle difference in the usage of pronominals, since the participants of our study attempted to feel empathy towards communities affected by the mining project, which would make the person stating the argument understand the situation from an experiential point of view.

This study has several implications for development and education. Regarding development, it is clear that, as development progresses, the number of arguments and mental models, and the variety of argumentation schemas, increase significantly. The variables that models are comprised of an increase in complexity, which is related to variable control. The control-of-variables strategy (CVS) is a prominent research area in the development of scientific reasoning (Kuhn, Ramsey & Arvidsson, 2015; Kuhn & Modrek, 2018), and it suggests that development affects the way variables that affect a phenomenon are managed, which allows for constant intentional manipulation in order to assess the effect of a focal variable on a given result. In our research, it is noteworthy, from a developmental point of view, that the diversity of mental models increases with age, along with the number of variables in each model. This would support views that state that typically scientific processes of problem-solving and argumentation can be found during adolescence (Kuhn, Hemberger & Khait, 2017).

We document the ability students have to argument from higher-order reasoning and the opportunity that teachers have to engage their students in productive and socially and scientifically relevant discussions by using social-scientific issues. Studies on argumentation have found that students do not follow systematic decision-making processes (Lee & Grace, 2012; Hsu & Lin, 2017); nevertheless, the decision-making framework gives students motivation and knowledge, such that it is possible to find students showing systematic reasoning in discussions about science and technology (Gutierrez, 2017; Uluçinar, & Aypay 2016). This report shows how students can model the situation under discussion, seeking an appropriate background to present arguments about situations that impact particular human groups in real contexts. Moreover, the use of socio-scientific issues seems adequate to engage students in motivating situations that let them use knowledge and discursive processes belonging to science to find socially agreed-upon solutions. This is something that has already been suggested from the standpoint of pedagogy (Develaki, 2016): to foster the mediating role of models for the application of theories to the real world, contributing to the development of new theoretical conceptions in students of different educational levels.

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Notes

* Research article.