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REVISTA INTERNACIONAL DE PESQUISA EM DIDÁTICA DAS CIÊNCIAS E MATEMÁTICA

Argumentação na ciência: hidroestesista versus hidrogeólogo

Argumentation in science: dowser versus hydrogeologist

Argumentación en ciencias: zahorí versus hidrogeólogo

Francisco González-García[1]
Raquel Gómez-Loarces[2]
Gracia Fernández-Ferrer[3]
Sila Pla-Pueyo[4]

Resumo: É apresentado um estudo sobre a capacidade de argumentação científica em estudantes da Formação Profissional Avançada em Saúde Ambiental. Os alunos completaram um exercício de três etapas, incluindo uma discussão no final de cada etapa. No final, eles tiveram que decidir entre contratar um hidrogeólogo ou um hidroestesista para achar água subterrânea (solução científica ou pseudocientífica). A análise dos argumentos resultantes indica que há uma falta de ligação entre as ideias anteriores dos alunos e os argumentos por eles utilizados. Para melhorar as competências de argumentação e literacia científica dos alunos, o pensamento crítico deve ser incentivado.
Palavras-chave: Argumentação. Hidroestesia. Águas subterrâneas. Pseudociência. Educação científica.

Abstract: A study of the capacity of scientific argumentation in students of Advanced Professional Training in Environmental Health is presented. Several groups of students carried out a three stages exercise, including a debate at the end of each stage. At the end, they had to decide between hiring a hydrogeologist or a dowser to find groundwater (scientific vs. pseudoscientific solution). Analysis of the resulting arguments indicates that there is a lack of connection between previous ideas from the students and the arguments used by them. We conclude that in order to improve the student's argumentation skills and scientific literacy, critical thinking must be encouraged.
Keywords: Argumentation. Dowsing. Groundwater. Pseudoscience. Science education.

Resumen: Se presenta un estudio de la capacidad de argumentación científica en estudiantes de Formación Profesional Avanzada en Salud Ambiental. Los estudiantes realizaron un ejercicio de tres etapas, incluyendo un debate al final de cada etapa. Al final tuvieron que decidir entre contratar a un hidrogeólogo o a un zahorí para encontrar agua subterránea (solución científica vs. pseudocientífica). El análisis de los argumentos resultantes indica que hay una falta de conexión entre las ideas previas de los estudiantes y los argumentos utilizados por ellos. Para la mejora de las habilidades de argumentación y alfabetización científica de los estudiantes se debe fomentar el pensamiento crítico.
Palabras-clave: Argumentación, Zahorí, Aguas subterráneas, Pseudociencia. Educación científica**.**

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[1] Licenciado y Doctor en Ciencias Biológicas. Profesor Titular de la Universidad de Granada. Facultad de Ciencias de la Educación. https://orcid.org/0000-0001-8127-9792. E-mail: pagoga@ugr.es
[2] Licenciada en Ciencias Biológicas. Profesora de Formación Profesional CEPA Enrique Tierno. https://orcid.org/0000-0002-2188-4402. E-mail: rgloarces@gmail.com
[3] Licenciada en Geología y Doctora en Didáctica de las Ciencias. Profesora Asociada de la Universidad de Granada. Facultad de Ciencias de la Educación. https://orcid.org/0000-0002-3530-8553. E-mail: gferfer@ugr.es
[4] Licenciada y Doctora en Ciencias Geológicas. Vicedecana de Internacionalización Faculta de Educación de la Universidad de Granada. https://orcid.org/0000-0003-4884-4096 E-mail: spla@ugr.es; vicinteducacion@ugr.es

Introduction

Groundwater functioning has traditionally been surrounded by a mystery halo, maybe due to the fact that it is a phenomenon hidden to the plain sight. Thus, it requires a high level of abstraction in order to understand it (WHITE & FORBES, 2021). Likewise, previous studies show the insufficient academic formation related to the alphabetization on this topic (ARTHURS, 2019; FERNÁNDEZ-FERRER & GONZÁLEZ-GARCÍA, 2010; LEE et al., 2019; WHITE et al., 2022). This lack of knowledge may reinforce the fact that nowadays, the dowsers are still sought to find water nowadays (HASSAN, 2020).

The words "dowsing" and "dowser" are related to the older word "douse", than means "to plunge into water". A more modern term, radiesthesia, is currently used, a neologism that uses the Latin term radium (meaning radiation) and the Greek term aesthesia (perception, ability to sense). In ancient times, the alternative word rhabdomancy was used instead, coming from the Greek words rhabdos (rod) and mancia (divination), referring to the use of a divining rod to find things below the ground. It has also been referred to as "water witching" (CHOW, 2005). Dowsing is not used just to find groundwater, but for divining purposes to find water pipes, broken pipes, buried electrical lines, lost people, buried foundations, archaeological sites, buried treasures, coal, oil, gold, gems, prehistoric trails and even lost people and in the field of medicine as a diagnostic tool (WHITTAKER, 2013).

The increase in popularity of radiesthesia throughout the years is parallel to the increase of the number of scientists trying to find a plausible mechanism to discredit this practice as superstitious or pseudoscientific such as those presented in Vogt and Hyman (2000) or McCarney et al. (2002).

A water-dowser (zahorí in Spanish) is a person to whom lay people attribute the "fabled ability of man to find water through divination". They typically use a magical or divining forked rod made mainly from flexible wood (hazelnut, birch, apple or olive wood) that they hold in their hands. They may use a pendulum instead (CHOW, 2005). This technique is called rhabdomancy or dowsing, and although it is been used to find oil and minerals, its more frequent application is to locate groundwater.

During the process of searching for water, the dowser holds the divining rod with both hands by the forked part, with the other end pointing to the ground while they walk, until they feel a pull on the rod or pendulum, which can hardly provide any reliable data on depth of water

nor yield (CHOW, 2005). The phenomenon that triggers the geomantic reflex or the movement of the rod or pendulum is explained as a faint magnetic anomaly that modifies the Earth's magnetic field, a fact that has been proved by using a magnetometer of magnetic resonance. However, it does not prove that such anomaly may produce any effect on the dowser's muscles and other studies reflect that the dowser's success is a random occurrence (ENRIGHT, 1999). Thus, the dowsing technique belongs to the pseudoscientific practices.

A pseudoscience may be defined as an ensemble of ideas and/or theories self-labelled as science but not meeting the scientific standards, as they cannot be contrasted through the usual workflow that characterizes the scientific method (PREECE & BAXTER, 2000; SHERMER, 2003). It is typical of pseudoscience to not admit the criterion of falsifiability, essential for science, always trying to avoid criticism or proofs against their principles.

Many studies show that pseudoscience are quite accepted among future teachers as well as in society in general (COSGROVE-MATHER, 2002; SOLBES, 2021). Thus, in many cases it may be ascertained that the social value or social perception of science is not proportional to the real importance it has nowadays. Science is undervalued or even mistrusted (MILLER, 2004), which is linked to an increasing irrationalism.

Preece and Baxter (2000) state that the growing acceptance of pseudoscience should be worrying for science educators, so one of the goals of scientific alphabetization must be to teach the difference between science and pseudoscience, as well as to develop a sceptical and critical way of looking at the information the students receive.

Several investigations point out that the degree of scientific literacy is not necessarily linked to a more sceptical vision (ARMENTIA, 2002; WALKER et al., 2002; RYAN et al., 2004), and that science fiction films and books have a higher impact on the social image of science and the scientists than the formal teaching of science (SOLBES, 2019; MENADUE, 2020). However, studies by science education researchers (LAUGKSCH, 2000) focusing on the Miller's (2004) dimensions of scientific literacy regarding science content knowledge and nature of science argue that an improved understanding of science and technology is advantageous to anyone living in a science- and technology-dominated society (MILLER, 2004).

Some of these studies show how within specific learning contexts, the wider the scientific literacy of a person, the higher degree of scepticism they enact (FERNÁNDEZ-

FERRER & GONZÁLEZ-GARCÍA, 2010; DAWSON & VENVILLE, 2010; QUEVEDO-ORTIZ et al., 2019). Knowing the processes and contexts of science, as well as its epistemology— that is, science as a mean of knowledge, its values and the inherent beliefs to the development of scientific knowledge— may contribute to developing critical thinking and scepticism in opposition to non-scientific forms of information (ABD-EL-KHALICK & LEDERMAN, 2023). Therefore, formal education must establish the basis for a more rational society, less prone to magical thinking (GÁMEZ, 2002).

There is a growing consensus about the importance of the development of argumentative skills to promote critical thinking and knowledge development in students (SOLBES, 2019). In this sense, argumentation, which is aligned with scientific thinking, is the ideal tool for the task. Argumentation is defined as the ability to create different points of view. Defending those points of view against alternative visions with a perlocutionary objective (FUENTES & ALCAIDE, 2007), which involves getting a behavioral or emotional response in the listener through speech, is essential for understanding the natural and social world (TOULMIN, 2003). Therefore, argumentation during science lessons may provide the students with the tools to create new meanings within the scientific context (ERDURAN et al., 2022).

The argumentative structure in science involves recognizing the targeted scientific problem, hypothesizing, designing experiments to clarify different questions, discussing results, recognizing those results by linking them to the evidences, spreading out the results and convincing the scientific community of the validity of the results through argumentation, providing not just the justification to the arguments but also comments to support or emphasize them (SOLBES 2019, 2021; SOLBES & TORRES, 2020).

In order to provide some insight on how to tackle critical thinking development in the science classroom, in this study the arguments given by the students to select science or pseudoscience are analyzed, focusing on their selection of the scientific practices of a hydrogeologist or the pseudoscientific actions of a dowser.

Methodology

The sample consists of 21 students of the first-year studies in Advanced Vocational Training in Environmental Health in Granada (Spain). The students were divided into groups

of four (G1, G2, G3, G4 and G5), except from the last one, that had five students in it. When displaying results, student names are cited with a name only.

A previous conceptions exploration survey was carried out to determine their mental models regarding the location and functioning of groundwater and their beliefs on the pseudoscience in which the present study focuses. In order to achieve this, part of a previous questionnaire (FERNÁNDEZ-FERRER & GONZÁLEZ-GARCÍA, 2010) was used, which facilitates the expression of students through drawings and writing.

Later on, a dilemma was posed to the students: "Is it more advisable to hire a hydrogeologist or a dowser?", and they had to orally express pros and cons. throughout the debate, within students of the same group, three sequenced activities were proposed.

Activity 1. The students were instructed to read the following text (the text has been translated into English for this publication):

"There are plans to install a drinking water supply in a town of a developing country that lacks of it. In order to do so, an expert hydrogeologist is sought, to give advice on the appropriate location to extract the raw water. As he is unavailable, the possibility to hire a dowser instead is considered. The dowser advertises himself in a newspaper as follows: "Dowser offers his services to seek groundwater. I have more than 20 years of professional experience and a high percentage of success. I collaborate with a company that performs the drilling once I have located the aquifer. I possess the knowledge to drill in the highest flow areas, avoiding brackish waters. Please call XXXX for further information, I will be glad to assist you".

Activity 2. The students were instructed to read two divulgation press articles in Spanish, Peláez (1995) and Cañas (2018). Peláez (1995) describes the situation that the farmers of Daimiel (Spain) lived during the intense draught that affected Spain from 1991 to 1995. The article mentions how the aquifer that supplies the farmers and the natural wetland (Tablas de Daimiel) is overexploited at that point, posing an ecological and economical risk for more than thirty towns in the surroundings. A team of scientists that work together with the farmers and the administrations are the short-term solution to the problem. Cañas (2018) explains that in Cádiz (Spain), a coastal city that has issues with the freshwater supply due to the salinisation of its aquifers, a hydrogeologist was hired to detect deep freshwater using underground electromagnetic tests.

Activity 3. The students are requested to watch two videos, one that shows an interview with a professional dowser and records him searching for water (Canal REDMÁS, 2014) and a second one that adverts a hydrogeological company by explaining the scientific methods that they use to find water (Canal REDMÁS, 2013).

The discussions among the members of each group were recorded at three different stages (Part 1, Part 2 and Part 3 from now on), corresponding to the debates developed at the end of each activity, in order to obtain recordings of the arguments developed in each part. The recordings were later transcribed and analysed for research purposes.

Three criteria were used to analyse the arguments proposed by the students to solve the dilemma: a) the logical relations or the way in which they connect new and previous arguments arisen during the debate; b) the content; c) if they finally choose the dowser or the hydrogeologist.

Regarding the first criterion, logical relations, the following categories were established, based on Toulmin's (2003) argument layout and using as a starting point Walton's (1996) categories for experts' arguments:

a. Cause: the speaker presents the rationale for a certain fact or opinion.

b. Consequence: the speaker presents the effects or sequels that may be inferred or deduced from the previously presented information.

c. Analogy or likeness: the speaker uses a situation that they consider similar to the one debated, in order to show its likeness or relation.

d. Contrast: the speaker presents an argument in the way of an idea or fact opposed to a different one. Stress is put on the contrast.

e. Exemplification: the speaker presents a specific case of a general fact in order to give an example of their point of view.

f. Personal experience argument: the speaker presents an argument by means of a personal experience, giving weight to their own opinion just because they have experience it.

g. Data: the speaker presents an argument containing numbers or statistics to support their or other people's opinions.

h. Authority argument: the speaker refers to a certain entity, institution or celebrity that supports their or other people's opinions.

i. Proverbs, idioms or mottos: the speaker uses in their argumentation a common expression that encloses popular and traditional knowledge to back the fact that they are trying to prove.

j. General knowledge argument: the speaker uses a generality that is well known by the other speakers and/or society to support their ideas.

In relation with the criteria of content, the following categories were established, also starting from Toulmin's (2003) argument layout and Walton's (1996) categories for experts' arguments:

a. Existential: the speaker argues by questioning the existence, truth or possibility of existence or occurrence of a certain topic.

b. Health: the speaker argues in favour of what is healthy and beneficial as opposed to what is damaging or harmful.

c. Usefulness: what is useful, necessary and effective is valued over what is useless, ineffective or dangerous. The speaker argues by questioning if the set or expected goals are met, if something is useful or effective.

d. Moral: the speaker argues by questioning if the topic is set within a certain scale of values.

e. Quantity: the speaker gives value to the fact that a topic affects a large number of people.

f. Quality: the speaker values quality over quantity. They argue by questioning whether minimal quality criteria are met to achieve a goal.

g. Beauty: The speaker gives value to beauty.

h. Progress: The speaker gives value to the new or original, technology and/or science.

i. Tradition: the speaker argues in favour of customs or habits practiced for a long time o since ancient times.

j. Pleasure: the speakers argue in favour of their desires and complacency, of what they find agreeable.

k. Hedonism: the speaker argues in favour of the brevity of life and the importance of living it fully, valuing the enjoyment of the present moment.

The results of the study are presented based on the above-mentioned three criteria, naming Analysis A the one regarding the logical relations criterion, Analysis B the one

regarding the content criterion and Analysis C the selection between dowser and hydrogeologist. The results regarding the misconceptions on location and functioning of groundwater will be presented at the end.

Results

The results from the study are presented hereby. In order to exemplify some contributions of the students at different stages of the debate, translations from Spanish into English are provided in these sections for those sentences directly transcribed from the Spanish oral debate. As literal translation does not always represent the real meaning of the speaker's contribution, the translation has tried to respect as much as possible the original idea or intention behind the oral contributions of the students.

Analysis A. Regarding the first criterion of analysis, logical relations, category "contrast" is the most frequently used, with a 33% (see Table 1).

Table 1. Table of frequencies of Analysis A, arguments depending on the logical relations criterion.

Argument category	Absolute frequency	Relative frequency
a. Cause	29	13%
b. Consequence	40	18%
c. Analogy or likeness	9	4%
d. Contrast	72	33%
e. Exemplification	13	6%
f. Personal Experience	11	5%
g. Data	17	8%
h. Authority	14	6%
i. Proverbs, idioms or mottos	1	1%
j. General knowledge	14	6%
Total	220	100%

Source: Own data

Some answers illustrating this category (“contrast”) are: "Imagine that he (the dowser) drills a well and then the water is polluted" (Ruth, group 1, part 1). "Maybe investing in a dowser means more trouble than benefits, while if you wait for the other (the hydrogeologist) (the result) is more reliable" (Lorenzo, group 5, part 1). "Moreover, the man (the dowser) says that he supposedly has a gift, doesn't he? But if you have a gift, then you will find water on your own, without needing a rod. And other people wouldn't be able to, would they?" (Lucas, group 5, part 3).

The second and third most frequently used categories are "consequence" and "cause", with an 18% and a 13% respectively (see Table 1). Some examples of using the "consequence" argument follow: “The problem is not the time they waste, but the money" (Rocío, group 1, part 1). “I still think that dowsers don't have a scientific background, that professionals are more reliable than dowsers" (Eva, group 4, part 2). “And it's also a danger for the terrain/ground (hiring a dowser). Imagine that he seeks an aquifer and it is deep. And then... I don't know, an earthquake and the ground crumbles" (Luisa, group 5, part 3).

Regarding the third category, "Cause", some examples are: "It is not a waste of time (hiring the dowser) anyway, as they have lived without that water their whole lives" (Rocío, group 1, part 1), “Because the dowser does not guarantee his success" (Álvaro, group 2, part 1). “I prefer the professional, because ...he has studied, which avails him, and he has a scientific background when exploring or drilling a well" (Eduardo, group 4, part 1).

The use of the rest of categories is represented by percentages under 10%. Some transcribed examples of these other categories are:

Analogy or likeliness: “It is like homeopathic medicines, they have no scientific background and I don't know why people still believe in those things, but...but come on, they shouldn't exist." (Efrén, group 4, part 2);

Exemplification: "For example, now he says ¡let's do it! Here, in the middle of town, you may have to dig, may have to remove houses" (Raúl, group 1, part 2);

Personal experiences: "But I have seen this work (dowser methods)" (Quique, group 3, part 1);

Data: “But they do have an error margin, maybe out of 20 cases, 5 have worked" (Quique, group 3, part 2);

Authority: “From my point of view, we should wait for the expert, there is a reason why he is an expert" (Quiterio, group 3, part 1);

Proverbs, idioms and mottos: “Exactly, cheap becomes expensive” (Lorenzo, group 5, part 2);

General knowledge: “I think that, if the...mmm dowser could do it... there would be methods nowadays and it would be much more in the general culture, that we would know about it" (Lucas, group 5, part 1).

Analysis B. A classification of the arguments based on the content criterion is shown in Table 2. The most frequently used categories are those referred to “Quality” (37%) and “Usefulness” (24%), both combining over the 61% of the usage frequency.

Table 2. Table of frequencies of Analysis B, arguments depending on the content criterion.

Argument category	Absolute frequency	Relative frequency
a. Existential	19	10%
b. Health	1	1%
c. Usefulness	47	24%
d. Moral	2	1%
e. Quantity	4	2%
f. Quality	70	37%
g. Beauty	0	0%
h. Progress	31	16%
i. Tradition	18	9%
j. Pleasure	0	0%
k. Hedonism	0	0%
Total	192	100%

Source: Own data

Examples of the "Quality" category are: "But, for example, a hydrogeologist may detect not just the presence of water, but water circulation, depth and other things. A dowser may tell you there is water here, but maybe not give you data such as the circulation it has, or other things, no?" (Lorenzo, group 5, part 1); “Moreover, the dowser doesn't know if the water is good or if it is bad, brackish, fresh... If the hydrogeologist tells you it is bad water, why would you dig a hole? And you save the money of drilling the hole" (Ángela, group 2, part 3).

Regarding the "Usefulness" category of argument, we have detected the following examples: “I wouldn't include finding water as the dowser's set of skills"(Andrés, group 2, part 1); “I think that...in terms of water for a city or a town or for whatever, it is not effective calling a dowser for...for that. He is not that reliable” (Lucas, group 5, part 2).

The category "Progress" is used by the 16% with examples such as the following: "There is more efficacy in the management with a scientific method, empirical and proved than with two rods of a guy that you don't even know what he has even found" (Quirico, group 3, part 2); “After reading the articles, I still think that I prefer the professional, as...he has studies that avail him and a scientific background when exploring or drilling a well" (Eduardo, group 4, part 2).

The next most used category is “Existential” (10%) with the following examples: "I personally, can't say it personally, because I have never seen one, I have never seen a dowser, but I can also tell you that from what appears in a newspaper, you can't trust even half of it, and that would be too much!" (Álvaro, group 2, part 2); “He, he carries it (the rod) in his hands as any other could do, why does he have to have a gift? If I walk by with the rods as he does, are the rods not going down? Am I not affected by that energy, or what?" (Lorenzo, group 5, part 3).

Another category with similar usage percentage is "Tradition" (9%), with the following examples: “In Africa... In Africa people do like this with the rods and they find it (water)” (Quique, group 3, part 1); “Let's see, if dowsers have been in use since medieval times, and there have been good results, they can be used nowadays as well" (Quintina, group 3, part 2).

The rest of categories have an incidental usage, with percentages below 3%. Some examples are:

Quantity: "Maybe if the dowser was for a peasant that needs water in his plot, then ok. But for the city and all that, then no" (Raúl, group 1, part 2);

Moral: “Well, it needs to be done in a different country, dude. We need to be charitable!" (Andrés, group 2, part 3)

Health: “You directly kill the population" (Ruth, group 1, part 1).

Categories "Beauty", "Pleasure" and "Hedonism" are not used at all.

It is worth mentioning the appearance of an argumentative category that is not included in the proposed classification. It would include the "Economy" arguments, in which the different speakers argue about the economical value in order to make a choice. A total of 43 arguments of this category were found (an absolute frequency closer to the "Usefulness" arguments, second in frequency related to content). Some examples are given below: “Let's see, I think... I think that... if the dowser costs a lot of money, then no, but if he is cheaper... no?” (Rocío, group 1, part 1); “As the owner of a plot, you will clearly go for the cheaper option, even more if it is a small area, if it is a large one...” (Quiterio, group 3, part 2): “The only advantage of the dowser is that... economically, he wins, because he is cheaper” (Luisa, group 5, part 2).

Analysis C. In the following table (see Table 3), the different conclusions reached by the five groups at the different stages of argumentation are shown.

Table 3. Conclusions reached by each group at the different argumentative stages.

	Conclusion 1	Conclusion 2	Conclusion 3
Group 1	Hydrogeologist	Hydrogeologist	Hydrogeologist
Group 2	Hydrogeologist	Hydrogeologist	Hydrogeologist
Group 3	Dowser if it is cheaper, if not, hydrogeologist	No explicit conclusion	No explicit conclusion (they drift away from the problem).
Group 4	Hydrogeologist	Hydrogeologist	Hydrogeologist
Group 5	Hydrogeologist, without fully discarding the dowser option	Hydrogeologist	Hydrogeologist, dowser if it is urgent or a minor job

Source: Own data

Conclusion 1 corresponds to the first argumentation stage, when they only count on their own knowledge. Conclusion 2 is expressed after reading the newspaper articles and conclusion 3 after they have watched the videos.

Table 4 shows the number of students that were or not familiar with the kind of work developed by a hydrogeologist, and which ones would choose or not a dowser to drill a well for a farmer. As it may be observed in the table, most of those who know what a hydrogeologist

does (5 out of 7 students) do not choose the dowser. On the other hand, two thirds of the class (14 students) are not aware of the kind of tasks that a hydrogeologist performs as part of their job. However, more than half of them (8 students) would still not choose the dowser for the job, with only one student that was sure that calling the dowser would be best.

Table 4. Results to the question: do you know the type of work that a hydrogeologist does?

		They know what a hydrogeologist does	
		Yes	No
They choose the dowser	Yes	0	1
	No	5	8
	Maybe	2	5

Source: Own data

Moreover, we have also analysed the answers to questions of the misconceptions exploratory test that will help us to determine the mental models of students about groundwater, taking into account its location and flow. For this purpose, the classification by Fernández-Ferrer and González-García (2010), in which the following categories of mental models are proposed: stagnant in pores, underground river, lake and underground river, underground lake, stagnant in pores and underground rivers, lake and flowing through pores, flowing through pores and incongruent. In the present study, six students present the "lake and underground river" model, while the other 15 presented the "incongruous" model, as it was not possible to deduce a model after their answers to the questionnaire or the drawing they made.

Discussion and conclusions

Regarding the analysis of the logical relations that the students establish when presenting their arguments (Analysis A), we highlight that the most frequently used category, "Contrast", is the most common relation in the scientific dialogue, as it is used to express restrictions and limitations for a certain hypothesis. Moreover, contrast may provide dialogue with a persuasion ability, attracting the attention of our conversation partner. In fact, contrast is typically used in advertising. Therefore, it is interesting to use it in the science teaching context, to capture the attention of the students and for them to become the ones using it, as its use is widespread in science.

It is also interesting to point out that argumentation shows two types of arguments (KLIX, 2004) that shape the creation of new scientific knowledge:

Deductive method: it explains reality starting from general theories (generalisations) and ending in particular cases, so not allowing for universally valid conclusions to be drawn. It is typical of formal sciences such as mathematics.

Inductive method: it proposes laws and general and probable conclusions starting from particular observations of facts and phenomena. It is used in empirical or experimental sciences such as biology or geology, based on the explanation of observable phenomena.

According to those definitions and following the workflow by Macagno, Walton and Reed (2017), in the analysis of logical relations (Analysis A) we can establish a correspondence between those two types of argumentations (KLIX, 2004) and the argumentative categories described earlier (based on those proposed by WALTON, 1996):

Deductive method: "Cause", "Consequence", "Contrast", "Exemplification", "Proverbs " and "General knowledge" arguments.

Inductive method: "Data", "Authority arguments", "Analogies" and "Personal experience" arguments.

Most of the logical relations categories found in the highest frequencies among our students (see Table 1) correspond to the deductive method (77% in total). We interpret that this may be due to the fact that nowadays, the teaching style is still too theoretical. In order to solve this issue, we believe a more experimental approach to science teaching should be promoted, as well as the use of the inductive method in the classroom, so the students would be more participative and they would better learn the usual process that science uses to create new knowledge. Therefore, both methods would contribute to the argumentative enrichment of our students.

Regarding the analysis of the of the arguments based on the content criterion (Analysis B), it is reasonable to think that the arguments most frequently used by the students, related to usefulness and quality (see Table 2), is a result of the scientific context of the debate that took place during the experiment.

In science, it is common to try to find useful solutions to complex problems, and those solutions must meet certain quality standards. We must not forget either the social and cultural context of the students, as usefulness and quality are crucial in our consumerist society. Using

these categories of argumentation to teach science would bring us closer to the reality in which our students are immerse. In this sense, the economical weight that the students give to their arguments seems to be linked to the recession environment in which the students, of an average age of twenty years, have grown up. From this point of view, we value the fact that our students give importance to quality and usefulness in their argumentation, thus suggesting that as part of the science teaching process, more emphasis should be made in the quality of scientific advances that have considerably contributed to our society.

Regarding the proportionally less used argumentation categories in Analysis B (Table 2), we would like to highlight the fact that most of the times that the "existential" argument was used, it questioned the truth of the dowser's methods but it did not argue the reason behind this questioning. This fact is in agreement with what Armentia said (2002), that most of our society benefits from science, but only a few question its truths or reasons.

Finally, and related to what we just mentioned, we will comment on the results for Analysis C. Practically all groups decided for the hydrogeologist at every argumentative stage, even when two thirds of the students were not aware of the tasks that a hydrogeologist performs as part of his job. However, it is worth mentioning that the materials supplied for activities 2 and 3 may have help them to become familiar with it. Moreover, if we review their mental models about location and functioning of groundwater, most of them fall within the "incongruous" model, as their selection of a hydrogeologist (symbolising science) or a dowser (symbolising pseudoscience) did not coincide with their scientific mental model. Therefore, we see from this analysis that it is possible for the students to choose the option which is considered to be the best from a scientific perspective, but it does not mean that they possess a mental model fitting the scientific model.

The minimal effect that education shows in the results of Analysis C may be due to one of the most common critiques to science teaching: the lack of connection between learning and student's daily life. This issue was detected early on, in the first proposals of a constructivist approach to education (SOLOMON, 1994). Thus, constructivism fails because of its inability to provide realistic "reconstructions" of knowledge about the natural reality, or it would only succeed to produce a scientific explanation in formal contexts (science classroom) but the students would go back to their misconceptions in any other daily context (VENVILLE, 2020).

As a general reflection, it is discouraging to see how little knowledge about groundwater the students of an environmental formative cycle have, as the future supply for many towns will depend on their responsible management of this resource. It is also worth reflecting on our educational system and the fact that a group of students that has undergone all of the educative stages, including pre-university courses, is not capable of developing a solid argumentation based on science.

Education plays then a critical role in fostering critical thinking (ERDURAN et al., 2022), so promoting criticism will engage the student's interest, making them a part of the process, so they do not see science as some inflexible discipline in which their opinion has no value (CADEMÁRTORI & PARRA, 2004; MARANGIO & GUNSTONE, 2020). We thus consider vital to promote critical thinking through activities including argumentation, as the lack of it could potentially result in a higher pseudoscientific believe in our students.

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