Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Learners' Conceptions About Geothermal Energy in Three Caribbean Islands

Claire Anjou, Frédéric Fournier, Yves Mazabraud and Thomas Forissier

ESPE de Guadeloupe, Morne Ferret, BP 517, 97178, Les Abymes, France

claire.anjou@espe-guadeloupe.fr

Keywords: Geothermal context, Students' conceptions, Guadeloupe, Martinique, Dominica.

ABSTRACT

Geothermal energy has a vast potential in the West Indies' Islands. The geological composition and the geodynamical properties of this area lead to a strong presence of hydrothermal activity, offering a favorable potential for the development of geothermal industry. In addition, the economic situation of these islands makes them dependent on hydrocarbons imports; this is why local politicians show an interest toward the development of this renewable energy in this area.

The study presented was conducted in three islands of the West Indies: Guadeloupe, Martinique and Dominica, and the purpose is to understand students' conceptions about geothermal. Combined with the development of other local renewable energies, geothermal energy offers an interesting potential that could allow these islands to acquire energy autonomy.

The West Indies are the volcanic islands resulting from the subduction of the North and South America plates under the Caribbean plate. Despite a relatively close geological context, the islands present different geothermal contexts and uses of geothermal energy. In Guadeloupe, a geothermal power plant located in Bouillante city exploits groundwater between 500 and 1000 meters deep at a temperature of 250°C. The electricity produced corresponds, over the last decade, to around 8% of the island's local energy consumption. In Dominica, despite a proven significant geothermal potential in the Roseau Valley, no geothermal power plant exists. However, several boreholes were drilled between 2011 and 2014. Finally, in Martinique, some exploratory studies were carried out, but there is currently no geothermal facility.

Geothermal conceptions of a representative sample (n=1349) of 14-15 years old students were collected in the three islands through a questionnaire including open and closed-ended questions, Likert scales and drawings. The collected data were analysed using statistical methods (descriptive, interdependence and multiple correspondence analyses). It reveals that students' conceptions about geothermal energy are very different between these three islands. In Guadeloupe, students associate geothermal energy with its industrial aspect as well as with volcanism and have a positive opinion of this energy. In Martinique, students link geothermal energy with its renewable trait, which is positive for the environment. In Dominica, the conceptions are oriented on the practical aspect of the resource and students have a positive opinion of it because of it's impact on economic development but they also fear a negative impact for the environment and safety.

This study discusses the context of conceptions about this energy. The conceptions about geothermal energy are strongly related to the geological, political, socioeconomic and cultural context. It seems important to take those differences into consideration for the education of this concept in this area. In addition, pedagogies could use this diversity of contexts and representations in educative approaches.

1. INTRODUCTION

The West Indies is a volcanic arc located at the boundary of the North American plate, the South American plate and the Caribbean plate. The volcanic islands that compose it are the result of North and South American plates subducting under the Caribbean. Guadeloupe, Dominica and Martinique are three adjoining islands of the Lesser Antilles. They have very similar geological contexts and host comparable geothermal bodies, but of different size and potential (Laplaige, Durimel, & Mompelat, 2013). The early state of research in Martinique makes the comparison of geothermal resource size irrelevant. The stages of exploration and exploitation of geothermal energy in these islands are very different.

Guadeloupe is a French territory that covers an area of 1 628 km² and has a population of 405 739 people. It has been exploiting its geothermal resource since the 1980s. Today, it produces 84 073 MWh, which corresponds on average to 8% of the of the island electricity consumption (Observatoire Régional de l'Energie et du Climat, 2017). This resource is located the geothermal field of Bouillante, which is on an ancient volcanic system and on the Montserrat fault, allowing the reservoir to have a good fluid circulation (Calcagno, Bouchot, Thinon, & Bourgine, 2012; Samper, Quidelleur, Lahitte, & Mollex, 2007). On this small island the main portion of energy, and electricity is produced with oil imports and combustion. The development of renewable energies in Guadeloupe is a real environmental concern but also has economic aims for the energetic autonomy. The development of renewable energies in Guadeloupe is a real environmental issue but also has economic aims for the energetic autonomy. Hence, Guadeloupe is a good target for geothermal studies of science education and social acceptance. In accordance with this study's findings, the Geotref Project's, objective is to improve the knowledge and the technologies about geothermal energy and to develop the industry in the area.

Martinique is a French overseas territorial community. Its area is 1 128 km² for 386 486 inhabitants and it does not produce geothermal energy. Martinique is 93% energy dependent in 2015, its renewable energy production amounted to 7% of the total electricity consumption (mainly wind and photovoltaic).

Finally, Dominica is an independent, Commonwealth member of the CARICOM (Caribbean Community) It is part of the Organization of Eastern Caribbean States14 (OECS) and of the Global Partnership for Education (GPE). It has a surface of 750 km² with 73 543 inhabitants. Dominica's economy is based primarily on tourism and agriculture. In the 1960s, hydroelectricity provided 90% of the island's energy needs. However, with the increase in local demand, currently, the three hydroelectric plants located on the Roseau River produce only 27% of the local electricity. Solar and wind energy combined produce 1% of the demand and the remaining 71% comes from the combustion of imported diesel (National Renewable Energy Laboratory, 2015). Despite the proven significant geothermal potential in the Roseau Valley, there is no geothermal power plant. However, three exploratory drill holes were completed between 2011 and 2012 (two in Laudat and one in Wotten Waven). Production drilling was conducted between 2013 and 2014 in Laudat and reinjection drilling in Trafalgar.

The development of geothermal education and didactic in the Lesser Antilles needs an enrichment of knowledge on conceptions of individuals. Beyond an estimation of public opinion, already provided in this context by an unpublished work leaded in 2014 (BVA Group, 2014), the study presented here aimed to collect information on the school populations' conceptions about geothermal energy in Guadeloupe, Martinique and Dominique. The objective was to identify the prior conceptions in these three islands, emanating from students who had not yet received specific education on geothermal energy. The study also cared about the personal opinions of the sampled population. Finally, it was important to know the relationship between the students' conceptions and the context in which they were constructed. This paper will shed light on learners' conceptions of geothermal energy, by means of a questionnaire survey conducted in public and private high schools at the second-grade level, in Guadeloupe, Martinique and Dominica.

2. THEORETICAL FRAMEWORK

Science education research has already revealed that teaching needs to take into account learners' prior conceptions. In the framework of geothermal education, conceptions are described according to the KVP model (Forissier, 2003). For a learner, the KVP system is comprised of knowledge (K), values (V) and standard social practices (P).

2.1 Conceptions and Context

Conceptions, in science education, are fundamental elements to consider for a better understanding of the learning process. Studies on conceptions usually provide a way to understand conceptual changes and sometimes learning obstacles. According to these theories, new knowledge is built upon prior conceptions, that have been constructed during individual life experiences and activities. Understanding students' prior conceptions about geothermal energy in given contexts is an important step in the creation of adapted pedagogies in this field and in these contexts (Giordan & de Vecchi, 1990). Conceptions are usually defined as an individual's complex system of organized knowledge regarding a concept (Anjou, 2018). According to Demougeot-Lebel and Perret (2010), conceptions can be defined as a mental attitude allowing someone to understand and interpret reality. They are often unconscious and affect our daily attitudes and actions. Conceptions are built according to the experience, the social environment, or even the professional environment. Most studies in the field show the influence of the individual's context but also of the object's context on the construction of conceptions. In the field of sustainable development, the idea of conception has been defined as a system of interactions between knowledge, values systems and standard social practices; the KVP system (Clément, 2004; Forissier, 2003). This definition crosses over and into other disciplines and is now commonly used in studies dealing with conceptions. According to this KVP model, the K pole refers to the common knowledge accepted by the scientific community. The V pole explains the judgment and reveals underlying opinions, beliefs, ideologies held, in addition to the philosophical, moral, ethical and scientific positions taken. The P pole aims to understand how the domestic, engineering and production actions serve as a reference to scholar activities.

2.2 Conceptions in Geoscience

There is a considerable amount of research on conceptions in the fields of physics, biology and geology and how they influence the learning processes (Astolfi, 1991; Cormier, 2015; Treagust & Duit, 2009). In the field of geosciences, there are many studies about prior conceptions as obstacles to learning. They may be described as heavy, dark, and large. The particular samples are often memorized by the students and not necessarily the characteristics of the rocks. Therefore, difficulties arise when the students need to identify new samples. If the limestone samples used during teaching are white or yellow, then the student may not be able to identify a limestone if it is gray. Rock classification errors can be linked to misinterpretations of the structure or texture of the rock. Thus, the holes in the volcanic scoria can be misinterpreted, and the sample can be associated to the rocks that comes from the see, that also have holes and thus be perceived as sedimentary instead of volcanic, just like slate, sometimes row in the sedimentary category because of the layers that compose it (instead of metamorphic) (Happs, 1983).

In 1998, Dove published a literature review on "alternative conceptions" that children can have about concepts related to Earth sciences. His study focused on the concepts of rocks, earthquakes, volcanoes, the structure of the Earth, relief and erosion. For each theme, he described alternative conceptions as a difficulty encountered by the learner. According to this study, earthquakes can be perceived as occurring only in hot countries, because of a too dry climate. With respect to the structure of the globe, he observed that many children believed that magma comes from the liquid heart of the Earth (Dove, 1998).

In a very different approach, Orange and Orange (1995) described the conceptions of primary and secondary students about volcanoes. He compared students' drawings and explanations to three explanatory models of the volcanic functioning within the history of science:

- the local model (Buffon, 1769): volcanoes contain hot matter in them that feeds an underground fire;
- the central model (Chevalier, 1875): the Earth is made up of molten material that escapes by means of "vast vents" that are volcanoes;
- the global model (Allègre, 1987): the terrestrial mantle is relatively solid, but its partial fusion, beneath the mid-oceanic dorsals and in the subduction zones, causes the formation of volcanoes.

Through the detailed description of student conceptions based on the three explanatory models, Orange draws a didactic grid of obstacles and breaks that can guide teaching. The “obstacle objectives” (Martinand, 1986), to be overcome, are the transitions from a local to a central, then to a global conception.

Many other studies exist dealing with students’ alternative conceptions about concepts that could be more or less close to the geothermal subject (Çoker, Çatlıoğlu, & Birgin, 2010; Gautier, Deutsch, & Rebich, 2006; Leather, 1987; Lillo, 1994; Tortop, 2012). However, there are only few studies dealing with the conceptions on the subject of geothermal energy.

2.3 Conceptions on Geothermal

A presentation was given in 2010 at the 19th Caribbean Geological Conference on the characterization of the conceptions about geothermal energy by 11 year old pupils, from three classes in different locations in Guadeloupe (Mazabraud & Forissier, 2010). Apart from this study, there are no published works on the didactic of geothermal energy. Furthermore, generally, the humanities studies carried out in this field relate to social representations or acceptance (Kępińska & Kasztelewicz, 2015; F. Malo, Raymond, & Malo, 2016; M. Malo, Moutenet, Bédard, & Raymond, 2015). An unpublished survey was conducted in 2014 on the three islands mentioned above, involving adult residents, social players and thought leaders. The survey revealed that despite an overall good knowledge of what geothermal energy is, expectations in terms of communication varied across the islands (BVA Group, 2014).

2.4 Educational System in the Three Islands

The educational system in Guadeloupe and Martinique are identical to France’s, with a few nuances. Indeed, since February 2017, the Life and Earth Sciences high-school official program has been adapted for Guadeloupe, Martinique, French Guiana, Reunion and Mayotte, and some of these adaptations concern materials that can be correlated to the field of geothermal energy. A column called "contextualization" specifies for each theme of the school program, examples, references or local resources to be used to illustrate the contents. For example: for the chapter "Earth in the solar system", teachers in French Guiana are invited to use resources from the Kourou Space Center. For this same chapter, the Guadeloupe and Martinique programs provide explanations for geological and geodynamic phenomena, based on the West Indies’ context and they prefer to use data from local data.

Dominica has its own educational system, resembling the British system. The national curriculum is organized in four key stages (compulsory internships) for all children. The first part of education: key stage 1 and 2 (“grade” K and 1-6) trains students from 5 to 11 years old. It is divided into five major areas: Language and Arts, Mathematics, Science, Visual and Performing Arts (VPA), and Health and Family Life Education (HFLE). Science, also known as science and technology, is divided into four sub-categories: life sciences, physical sciences, earth and space sciences, and agricultural sciences. The second part of the curriculum: key stage 3 and 4 (“form” 1 to 5) trains students from 12 to 16 years old. The subjects are organized in two groups: compulsory core subjects and optional subjects. There are eight compulsory subjects: language, mathematics, science and technology (including information and communication technologies), agriculture, social sciences, HFLE (Health and Family Life Education), VPA (Visual Performing Arts) and physical education (*National curriculum framework for Dominica*, 2006).

3. METHODOLOGY

3.1 Sampling

To understand students’ conceptions about geothermal energy, and to examine the relationship between context and conceptions, a questionnaire survey was conducted in three Caribbean islands: Guadeloupe, Dominica and Martinique. The survey was conducted with a representative sample of students in the 14-15 age group. 496 students were interviewed in Guadeloupe, 372 in Dominica, and 481 in Martinique, for a total of 1349 students. The minimum representative number has been calculated using the same methodology as explained in Vaillant (2010). According to this methodology, a minimum of 342 students needs to be questioned in Martinique, for the target population of 3040 individuals. Facing the poor quantity of data available for Dominica, a similar target population as in Guadeloupe was used. This is sufficient for it to be representative since the Dominican population is much smaller than Guadeloupe’s. The number of students per island and per school is explained in Figure 1, as well as the location of the schools on the three islands. The survey was conducted in Guadeloupe and Martinique from September to October 2016, and in Dominica during the month of April 2017.

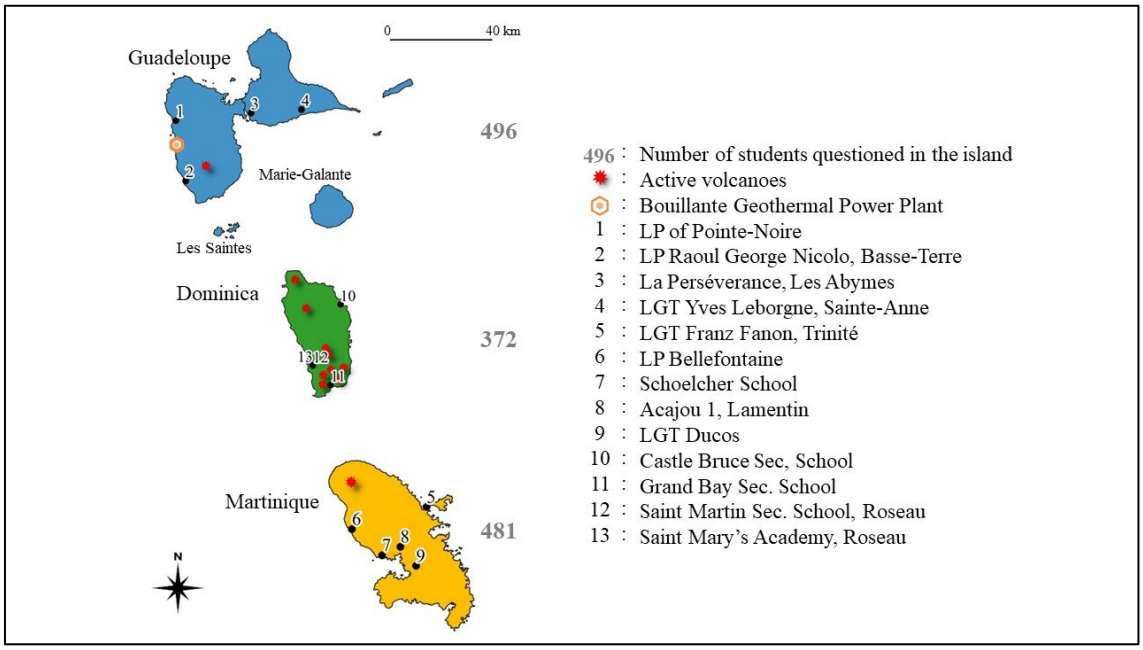

Figure 1: Map of the surveyed schools and position of volcanoes and power plants.

3.2 Questionnaire

Inspired by the KVP model described in the theoretical part of this paper, the survey was designed with various types of questions having different objectives about knowledge (K), values (V) and standard social practices (P), (Table 1).

Table 1: Summary table of the questionnaire.

N°	Type of question		Questions
Q1	Open-ended questions	Knowledge	What is geothermy? (give your own definition)
Q2			What is geothermy used for?
Q3: A to Q	Likert scale	Values and standard social practices	Give your opinion about the following sentences: geothermy… Is a well-controlled technique Need to be improved Is a clean energy Is a permanents available energy Is an economic asset to exportation Contributes to energy independence Contributes to sustainable development Contributes to protect the environment Creates employment Generates ecotourism activities Reduces household electricity bills Harms the environment Harms the biodiversity Harms human health Creates a risk for subsoil Harms the tourism activity Is profitable
Q4	Drawing	Knowledge	Draw a geothermal exploitation. You can add legends and explanations.
Q5	Open-ended question		Do you know any infrastructures related to geothermy? Which ones?
Q6	Close-ended questions	Standard social practices	Have you ever heard about geothermy?
Q7			Where have you heard about it more often?
Q8a			Have you ever heard about it in class?
Q8b			If yes, in what context?
Q8c	Open-ended questions		If yes, what grade were you in?
Q8d			If yes, what did you learn?
Q9a	Likert scale	Opinion	Are you rather for or against the development of geothermal energy?
Q9b	Open-ended question		For what reason(s)?
Q10	Close-ended questions		Do you think that you are well informed about it?
Q11a			Would you like to talk about it more often?
Q11b			If yes, with whom?

3.3 Data Processing

For each open-ended and close-ended question, processing modalities were established after a complete transcription of the answers. The processing will be outlined for the questions Q1, Q4, Q7 and Q9b. For these four questions, examples of answers will be presented for each modality. Since the answers are in French for Guadeloupe and Martinique, they have been translated.

Question 1: What is geothermy? (give your own definition).

For this question, eight response modalities were created to process the data (Table 2) and several modalities can be attributed to one answer.

Table 2: Answers modalities for the question 1.

Modality 1	Answers referring to an energy without specifying the origin or the purpose.
Modality 2	Answers referring to the energy or internal heat of the Earth.
Modality 3	Answers referring to electrical energy only.
Modality 4	Answers referring to renewable energy or the environment, ecology or nature.
Modality 5	Answers referring to fossil or nuclear energy.
Modality 6	Answers claiming that geothermal is the study of the Earth, confusion with geology.
Modality 7	Other answers, not falling into any of the mentioned categories.
Modality 8	No answer.

Question 4: Draw a geothermal exploitation. You can add legends and explanations.

In order to analyse the drawings, a list of 18 elements was established, and coding was carried out depending on the presence, or absence of the element in the drawing. Identified elements can be related to concepts having a link to geothermal energy. Sometimes, it may be easily identifiable objects (heat, electricity, volcanism) or concepts that, the researchers felt contributed to an overall understanding of geothermal energy and its industrial production process (for example: transformation, transfer, uses or distribution). Table 3 presents the 18 elements depicted in the drawings' observation.

Table 3: Presentation of the elements identified in the drawings.

1.Heat	Explicit representation of heat phenomenon (legends, thermometer, red colour).
2.Ground	Representation of the soil or subsoil or different layers of the earth.
3.Transfer	Transfer of heat or fluid between two different environments (drilling or arrows)
4.Transformation	Representation of a turbine or a system of heat transformation into electricity.
5.Power Plants	Exact presence of a factory, an industrial building or a geothermal power plant.
6.Uses	Representation of light, electrical appliances, heating, hot water or showers.
7.Electricity	Schematization or legends of electricity (presence of a bulb or an electrical network).
8.Distribution	Notions of the redistribution of the product towards houses, a city or another country.
9.Individual	Reference to individual geothermal energy for the production of heat or air conditioning
10.Tubes	Presence of a pipe network or conduit.
11.Drills	Representation of the action of drilling in the soil.
12.Groundwater	Presence of water or underground fluid, or groundwater.
13.Volcanism	Drawings of a volcano, lava or magma, or volcanic rocks.
14.Humans	Presence of one or more humans in the drawing.
15.Nuisance	Presence of smoke or explicit representations of something harmful or pollutant.
16.Earth	Drawings representing the planet Earth.
17.Renewable	Representation of one or more renewable energies.
18.Active Sun	Presence of the sun and of an explicit action of this sun

Due to the difficulties that may occur in the interpretation of the drawings, a double-blinded treatment was conducted. The compared analysis revealed a 9.73% difference between the two treatments. The treatment was conducted by the researcher in charge of the data collection and by a student external to the study. For the analyses presented in this paper, the treatment carried out by the student was kept, to remove any possible bias that could be caused by the proximity between the researcher and the project.

Question 7: Where have you heard about it more often?

Question 7 is a close-ended question, with six answers modalities, and the students have the possibility to select several choices.

- Family;
- School;
- Friends;
- Media;
- No answer;
- Other.

Question 9b: For what reason(s) (are you rather for or against the development of geothermal exploitation)?

The treatment of this open-ended question is illustrated in Table 4. Several modalities can be attributed to one answer.

Table 4: Answers modalities for the question 9b.

Modality 1	Answers referring to the environment or nature.
Modality 2	Answers referring to economic development and to the unlimited aspect.
Modality 3	Answers claiming the merits of geothermy (other than environmental and economic).
Modality 4	Answers referring to the negative aspects of geothermy
Modality 5	No knowledge or does not know
Modality 6	No interest
Modality 7	No answers

3.4 Data Analyses

Three types of analyses were carried out: descriptive analyses, inferential analyses (Khi², ANOVA) and multiple correspondence analyses (MCA). The descriptive analyses display the percentages of each answers' type. The inferential analyses indicate if the differences between independent groups of people are significant. The MCA allows us to understand the structure of a set of variables and the dependencies between the different variables' modalities.

4. RESULTS

This section presents the descriptive analyses as well as Khi² results for questions 4, and a multiple correspondence analyses made with the questions Q1, Q4, Q5, Q6, Q8a and d, Q9a, Q10, Q11a and the schools.

4.1 Descriptive Analysis and Khi²

For the questions Q1, Q4, Q7 and Q9b, some examples of answers will be illustrated, followed by a marginal distribution histogram describing the answers distribution for each question and the Khi² test explaining the significance of the differences between the three islands.

Question 1: What is geothermy? (give your own definition).

The table below gives some examples of answers to question 1, for each modality (Table 5).

Table 5: Examples of answers of each modality

Modality 1	"Geothermy is a source of energy it serves to create energy.", "I think it's an energy."
Modality 2	"It is an energy released by the heat of the earth's core."; "I think it's energy coming from the ground."; "Natural energy obtained from land.", "Heat from the earth."
Modality 3	"Geothermy is an energy that makes it possible to produce electrical energy."; "Geothermy is hot water used to produce electricity."
Modality 4	"Renewable energies"; "Geothermal energy is a renewable resource and it is a resource we used"
Modality 5	"Geothermal is a fossil study that digs underground"; "In my opinion, geothermal is a process that uses fossil energy to create energy."
Modality 6	"Geothermal is a study of the soil in the basement"; "Geothermal energy in my opinion is a soil study"
Modality 7	"Anything dealing with wind"; "Geothermal is a computer program"

The histogram (Figure 2) shows the distribution of answers in percentage for each response category, for each of the three islands. For this question, if the answer falls into several categories, several modalities are assigned to the learner's answer.

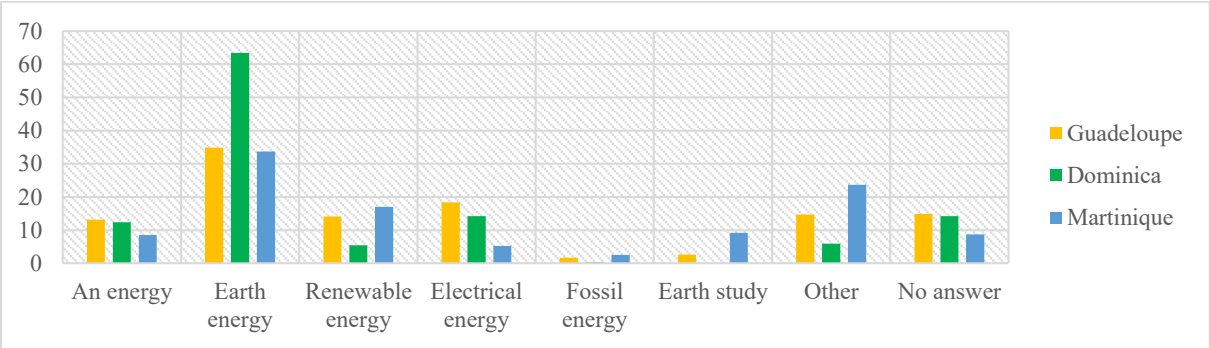

Figure 2: Descriptive histogram of question 1 answers, in percentages: Geothermal energy is...

The term "geothermy" is generally understood by the students of the three islands. It is, nevertheless, a little more well understood in Dominica where 63% of the students gave an answer related to Earth energy. The relationship to electricity is more often given by the students of Guadeloupe (18%) and Dominica (14%) than by those of Martinique (only 5%). The renewable aspect is more often touched upon by the students of Martinique (17%) and Guadeloupe (14%) than for the students of Dominica (only 5%).

Question 4: Draw a geothermal exploitation. You can add legends and explanations.

For the fourth question, a drawing of each island and its corresponding modalities have been depicted below in order to illustrate concrete examples of the processing (figure 3).

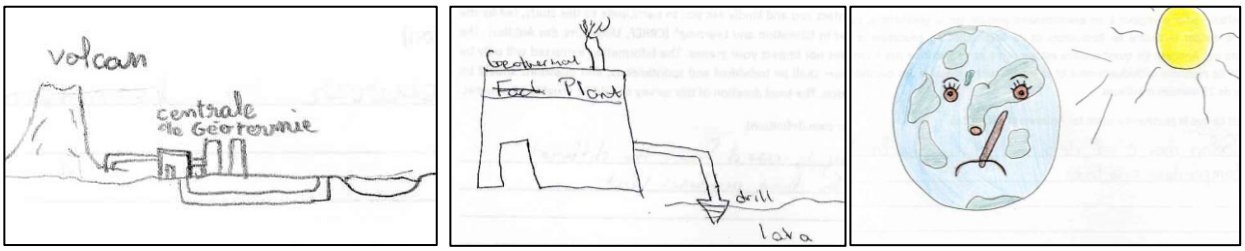

Figure 3: Drawings collected from left to right Guadeloupe (ground, plant, tubes and volcanism), Dominica (ground, plant, drill and volcanism) and Martinique (Earth and active sun).

A total of 926 drawings were collected. The processing of the drawings made it possible to carry out a descriptive statistical analysis. The histogram (figure 9) reveals the percentage of students who represented each element, according to the island of origin.

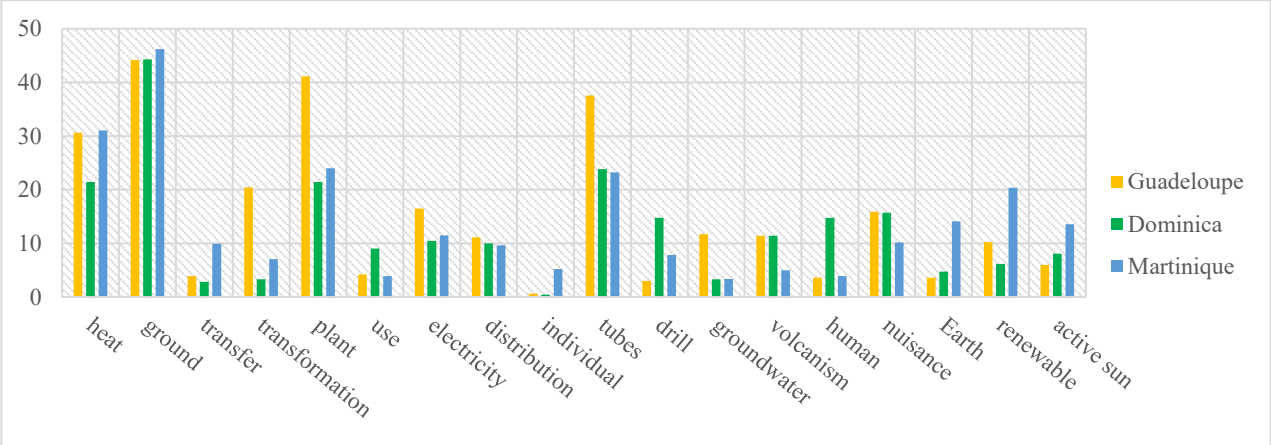

Figure 4: Descriptive histogram of the elements represented in the students' drawings, in percentages, for each island.

The most represented elements for each of the three islands are the same: ground, heat, plants and tubes. In addition to these four elements, the most represented element in Martinique is: renewable energies, in Guadeloupe: transformation, and in Dominica: nuisance. Beyond this first observation, a closer examination revealed specific response patterns for each island. In Guadeloupe, plants, tubes, transformation, and groundwater are much more represented in the drawings compared to the other islands (respectively around 20%, 15%, 13% and 8% more). Conversely, drills are a lot less drawn. In Dominica, humans, drills and uses are more drawn than in the other islands (respectively 9, 10, and 5% more in average) whereas heat is less drawn (-10%). In Martinique, renewable energies, Earth and individual installations are more represented than in other islands (respectively 12, 10, and 5% more on average) whereas volcanoes are less drawn (-6%). The Khi² test confirms that the elements drawn are significantly different according to the island ($\chi^2 = 283.45$, $df = 34$, and $p = 0$).

Q7: Where have you heard about it (geothermy) more often?

The question was a close-ended question with six answers modalities, for which students sometimes selected several answers. The answers distribution is detailed in figure 4 below for each island, in percentages.

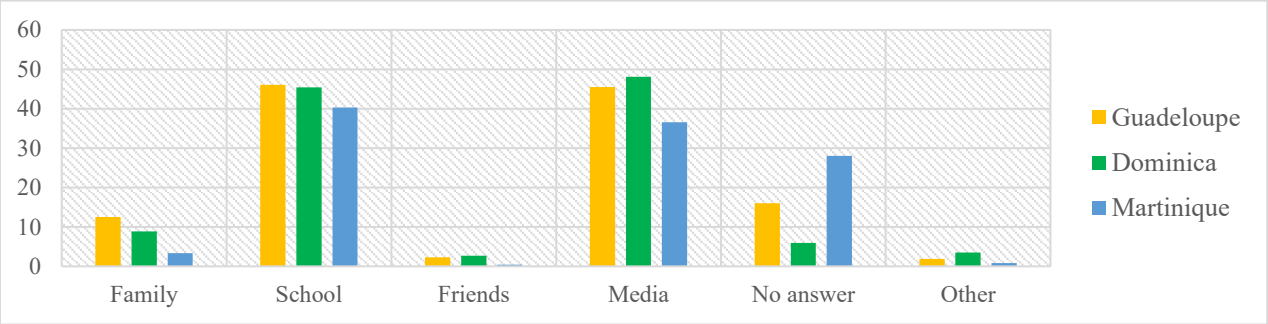

Figure 5: Descriptive histogram of question 7 answers, in percentages.

In the three islands, the most popular context in which the students heard about geothermal energy was at school and in the media. In fact, 46% and 45% of the student from Guadeloupe, 45% and 48% from Dominica and 40% and 37% from Martinique had heard about it respectively in school and in the media. Only 13% of the students from Guadeloupe had talked about geothermy with their family compared to 9% and 3% in Dominica and Martinique.

Question 9b: For what reason(s)? (Are you rather for or against the development of geothermal exploitation)

The table below gives some examples of answers to question 9b, for each modality (Table 6).

Table 6: Examples of answers of each modality

Modality 1	"To decrease the amount of fossil fuels in the air."; "It does not harm the environment or organisms in the environment."; "it is a natural energy."
Modality 2	"It is less costly for the inhabitants."; "Because it can reduce electricity bills."; "Employment on the island."
Modality 3	"Because it helps people."; "It is a good alternative way to produce energy."
Modality 4	"It will spoil the nature"; "It can destroy the soil."; "It can cause earthquakes or awaken volcanoes."
Modality 5	"Because I don't know what the use is."; "I'm not completely educated about it."
Modality 6	"I don't care."; "I am not interested in these kinds of things."

The question 9b was an open-ended question for which seven answers modalities were established. Sometimes, several modalities may be attributed to an answer. The answers distribution is detailed in figure 6, below, for each island, in percentages.

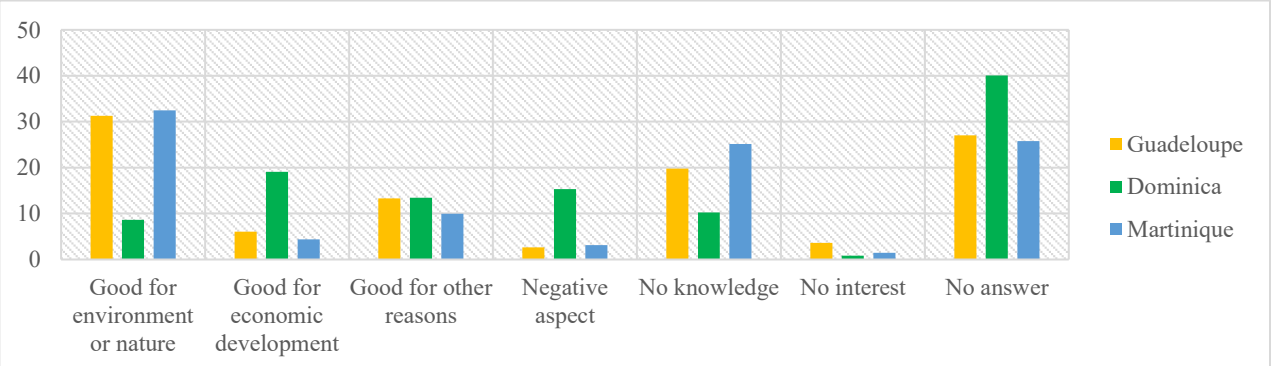

Figure 6: Descriptive histogram of question 9b answers, in percentages.

In Guadeloupe and Martinique, the reasons that the students are favourable to the development of geothermal energy appear to be homogenous: 31% and 32% cite a positive impact on the environment compared to only 9% in Dominica. In contrast, 19% of Dominican students are favourable for economic reasons, whereas only 6% in Guadeloupe and 4% in Martinique. In total, 51%, 41% and 47% respectively for Guadeloupe, Dominica and Martinique have a good reason to support the development of geothermal energy. In Dominica, 15% of the surveyed students are unfavourable and believe there is a negative impact caused by this industry compared to only 3% in Guadeloupe and in Martinique. In the three islands, around 50% of the surveyed students did not answer the question because of a lack of knowledge, interest, or because of an unknown reason.

4.2 Multiple Correspondence Analysis

Several interdependence analyses (MCA) were made. The MCA presented here was made with the questions Q1, Q4, Q6, Q8a and d, Q9a, Q10, Q11 and with the schools (Table 1). Figure 7 below is a representation of the MCA with the questions cited, according to two dimensions.

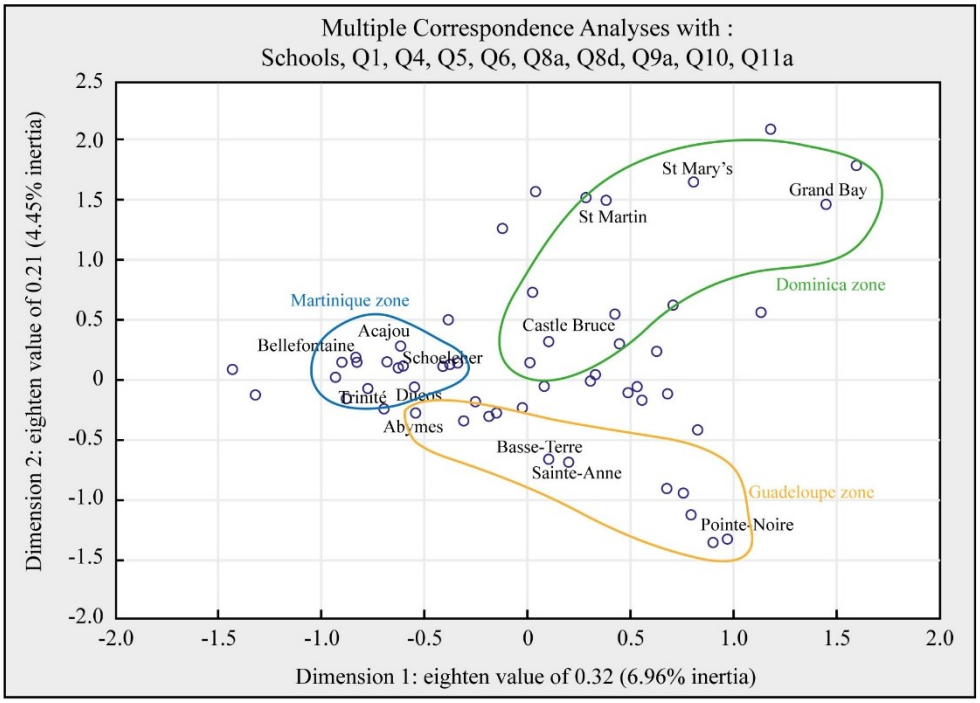

Figure 7: MCA representation and schools gathering by island.

Figure 7 illustrates the relationships between the variables cited, but here, only the variable "school" was reported. This representation was used because it reveals the proximity between schools from the same island. The conceptions expressed by the students in the questionnaire are gathered according to the territory in which the students live. According to this MCA, the conceptions in the different schools in Martinique are very close, whereas they are more diversified in Guadeloupe and in Dominica. This MCA also reveals an opposition on the first dimension (D1) between the conceptions in Martinique on the one hand and Guadeloupe and Dominica on the other hand.

CONCLUSIONS

According to the analyses, it was revealed that students in the three islands possess good knowledge of geothermal energy. They know that it is an energy that comes from the Earth, used to produce electricity, and that it is a renewable energy. However, the conceptions vary depending on the island. In Guadeloupe, students associate the concept of geothermy with its industrial aspect and with the volcanism. In Martinique, students link the concept of geothermy to the environmental aspect and to nature. In Dominica, it is linked to the industrial aspect, but also to the economic and practical aspect.

Generally, the students have a good opinion about the development of the geothermal industry on their island. The opinions are very homogenous in Guadeloupe and in Martinique but, in Dominica, it is different. Opinions in Dominica are less favourable, and students fear a negative impact of geothermal energy on the environment and their health, more so than on the other islands. They also fear the increase of volcanic and seismic risks.

Finally, the various MCAs show that the students' conceptions are very close between the schools on a same island. This confirms the premise hypothesis of similar conceptions originating from the same island. The other MCAs also systematically reveal two oppositions: (1) Guadeloupe and Dominica with a technology knowledge compared to Martinique with a more sustainable development knowledge; (2) Guadeloupe and Martinique with a favourable opinion against Dominica with a less favourable opinion regarding the development of the geothermal industry.

In Guadeloupe the geothermal plant of Bouillante is well known, but a better understanding and knowledge about the concept in the schools that are geographically closer to the plant (Basse-Terre and Pointe-Noire schools and especially Pointe-Noire school, by the students living in Bouillante) were noted.

The hydrothermal activity in Dominica is important and well-known. There are several spas and recreation centres in the Roseau Valley, where the natural heat of the water is used. There are also many hot springs and natural hot baths. In addition, there have been efforts to develop geothermal industry in Dominica for many years. Several drillings have been conducted but there is no production well. People may be aware of the existence of many natural hot springs. Finally, the various attempts to develop geothermal energy as well as investment made by the Dominican government have been highly publicized. All of these reasons can explain the knowledge awareness of geothermal energy among local populations. Geothermal power in Dominica is undoubtedly what Zeidler, Sadler, Simmons, and Howes (2005) consider to be a socio scientific issue.

The diversity of the conceptions, the contexts and their interaction can raise global concern for the importance and inclusion of context and conceptions in teaching, and the pertinence to design adapted teachings:

- Can geothermal energy be taught the same way on the three islands? On all the islands of the Lesser Antilles? In two countries?
- Can teachings about geothermy be designed based on contexts? Based on conceptions?
- Can conceptions and contexts be at times obstacles to learning?

All these questions are entrance ways to other research in the field and need to be studied in view of the creation of a geothermal teaching in the area.

AKNOWLEDGEMENTS

The authors would like to thank the GEOTREF project for financial support. This project is funded by ADEME in the frame of les investissements d'avenir program. Partners of the GEOTREF project are Kidova, Teranov, Mines ParisTech, ENS Paris, GeoAzur, Georessources, IMFT, IPGS, LHyGes, UA, UCP-GEC.

REFERENCES

Allègre, C. (1987). *Les fureurs de la Terre*: Odile Jacob.

Anjou, C. (2018). *L'énergie géothermique: représentations, enseignements et contextes aux Antilles et dans la zone caraïbe.* Université des Antilles,

Astolfi, J.-P. (1991). Quelques logiques de construction d'une séquence d'apprentissage en sciences. L'exemple de la géologie à l'école élémentaire. *Aster, 1991, 13" Respirer, digérer: assimilent-ils?".*

Buffon, G.-L. (1769). *Histoire Naturelle* (Vol. Tome 2). Paris.

BVA Group. (2014). *Evaluation des représentations cognitives de la population de la Guadeloupe, de la Martinique et de la Dominique vis-à-vis de la géothermie et des ENR*. Retrieved from Unpublished repport.:

Calcagno, P., Bouchot, V., Thinon, I., & Bourgine, B. (2012). A new 3D fault model of the Bouillante geothermal province combining onshore and offshore structural knowledge (French West Indies). *Tectonophysics, 526*, 185-195.

Chevalier, C. (1875). *Géologie contemporaine*. Tours, Marne.

Clément, P. (2004). *Science et idéologie: exemples en didactique et épistémologie de la biologie.* Paper presented at the Actes du Colloque Sciences, médias et société. ENS-LSH.

Çoker, B., Çatlıoğlu, H., & Birgin, O. (2010). Conceptions of students about renewable energy sources: a need to teach based on contextual approaches. *Procedia-Social and Behavioral Sciences, 2*(2), 1488-1492.

Cormier, C. (2015). Étude des conceptions alternatives et des processus de raisonnement des étudiants de chimie du niveau collégial sur la molécule, la polarité et les phénomènes macroscopiques.

Demougeot-Lebel, J., & Perret, C. (2010). Identifier les conceptions de l'enseignement et de l'apprentissage pour accompagner le développement professionnel des enseignants débutants à l'université. *Savoirs*(2), 51-72.

Dove, J. E. (1998). Students' alternative conceptions in Earth science: A review of research and implications for teaching and learning. *Research Papers in Education, 13*(2), 183-201.

Forissier, T. (2003). *Les valeurs implicites dans l'éducation à l'environnement : analyse de la formation d'enseignants de SVT (Sciences de la Vie et de la Terre) et des conceptions de futurs enseignants français, allemands et portugais.* Lyon 1,

Gautier, C., Deutsch, K., & Rebich, S. (2006). Misconceptions about the greenhouse effect. *Journal of Geoscience Education, 54*(3), 386-395.

Giordan, A., & de Vecchi, G. (1990). *Les Origines du savoir: des conceptions des apprenants aux concepts scientifiques* (D. e. niestlé Ed.).

Happs, J. C. (1983). Using socio-cognitive conflict to establish an understanding of the scientific meaning of rock. *Research in Science Education, 13*(1), 61-71.

Kępińska, B., & Kasztelewicz, A. (2015). Public Perception of Geothermal Energy in Selected European Countries. *Europe, 54*(5,520), 44-62.

Laplaige, P., Durimel, H., & Mompelat, J.-M. (2013). Développement de la géothermie dans la Caraïbe. *Geosciences, 16*, 26-35.

Leather, A. (1987). Views of the nature and origin of earthquakes and oil held by eleven to seventeen year olds: Geology teaching, v. 12.

Lillo, J. (1994). An analysis of the annotated drawings of the internal structure of the Earth made by students aged 10–15 from primary and secondary schools in Spain. *Teaching Earth Sciences, 19*(3), 83-87.

Malo, F., Raymond, J., & Malo, M. (2016). *L'acceptabilité sociale des projets d'énergie géothermique au Québec: Rapport final*: INRS, Centre Eau Terre Environnement.

Malo, M., Moutenet, J.-P., Bédard, K., & Raymond, J. (2015). *Public Awareness and Opinion on Deep Geothermal Energy in the Context of Shale Gas Exploration in the Province of Québec, Canada.* Paper presented at the Proceedings of the World Geothermal Congress, Melbourne, Australia.

Martinand, J.-L. (1986). Connaître et transformer la matière.

Mazabraud, Y., & Forissier, T. (2010). *De l'effet du contexte sur les conceptions d'élèves de 11 ans sur la géothermie en Guadeloupe*. Paper presented at the 19th Caribbean Geological conference, Gosier, Guadeloupe.

National curriculum framework for Dominica. (2006). Retrieved from http://www.ibe.unesco.org/curricula/dominica/dq_al_fw_2006_eng.pdf

National Renewable Energy Laboratory. (2015). Energy Transition Initiative, Islands. In.

Observatoire Régional de l'Energie et du Climat. (2017). *Les chiffres clés de l'énergie en Guadeloupe, Bilan 2016*. Retrieved from

Orange, C., & Orange, D. (1995). Géologie et Biologie: analyse de quelques liens épistémologiques et didactiques.

Piaget, J. (1929). *The child's concept of the world*. Londres: Routldge & Kegan Paul.

Samper, A., Quidelleur, X., Lahitte, P., & Mollex, D. (2007). Timing of effusive volcanism and collapse events within an oceanic arc island: Basse-Terre, Guadeloupe archipelago (Lesser Antilles Arc). *Earth and Planetary Science Letters, 258*(1-2), 175-191.

Tortop, H. S. (2012). Awareness and Misconceptions of High School Students about Renewable Energy Resources and Applications: Turkey Case. *Online Submission, 4*(3), 1829-1840.

Treagust, D. F., & Duit, R. (2009). Multiple perspectives of conceptual change in science and the challenges ahead. *Journal of Science and Mathematics Education in Southeast Asia, 32*(2), 89-104.

Vaillant, J. (2010). Eléments de statistique.

Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: A research-based framework for socioscientific issues education. *Science education, 89*(3), 357-377.