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

Teaching Geothermal Energy using Context Effects Approach

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: Pedagogical experiment, context effects, conceptions, design-based research

ABSTRACT

The purpose of our study is to provide new insights on the relations between geothermal energy and society and to shed light on solutions in the realm of geothermal education. We set up an experiment in order to propose a designed pedagogy approach built around context and students' conceptions. This innovative approach consists in a scientific inquiry based on context, associated with collaborative work between students who are living in places where geothermal energy contexts can be very different: Guadeloupe (Lesser Antilles) and Quebec (Canada).

Guadeloupe is a volcanic island located on a subduction area, providing a strong potential for high-temperature geothermal energy. The Bouillante geothermal plant produces about 8% of the Guadeloupe local demand for electricity. In Quebec, geological and geodynamical contexts are different: very low-temperature geothermal energy is used mostly to regulate temperature in buildings (for heating and air-conditioning). Our experiment is based on a preliminary calculation of differences between the geothermal contexts in those two regions. The calculation is done through a modeling of geothermal contexts in Guadeloupe and Quebec. Its pedagogical purpose is to provide the teachers with suggestions for the creation of learning scenarios, facilitated by the confrontation of distant students' conceptions. This confrontation can lead to the emergence of context effects. Those context effects are phenomenon that allow the learners to realize the contextuality of their own conceptions and therefore to share and acquire open conceptions and diversified knowledge.

During the experiments two types of data were collected: video recordings of students' interactions between Guadeloupe and Quebec, and pre and post-test questionnaires containing students' conceptions about the general concept of geothermal energy. Thanks to the analysis of video recordings (verbal, para-verbal and non-verbal analysis), it has been observed that context effects often result into changes in students' emotional states (surprise and astonishment for example). Pre and post-test aiming to collect students' conceptions before and after the experiment also highlights the existence of learners' conceptual changes associated with their learning process.

The experiment reveals that geothermal education can be designed by taking into account not only learners' prior conceptions, but also their local context in order to anchor knowledge on geothermal energy and facilitate learning. It can also include other contexts so the students can acquire more global and more expert knowledge about this concept. The context effects-based approaches can be a support for the creation of innovative pedagogies which will improve the rise of cognitive processes, helping with the learning of new knowledge. In addition, in relation with the sustainable development principles, context effects-based approaches, in education, provide to the students a local understanding of scientific concepts, combined with a global appreciation of needs, resources and applications of those scientific concepts.

1. INTRODUCTION

In the field of science education, the relationship between learners' conceptions about a studied object and the context in which this object is studied can be very significant (National Research Council, 2000; Renouard & Mazabraud, 2018). With respect to the geothermal object, this relationship was determined by a survey that was conducted using representative samples of a certain age group from three islands in the West Indies with different geothermal contexts: Guadeloupe, Dominica and Martinique (Anjou, 2018). This finding confirms the benefits of taking into account contexts during the teaching.

A pedagogical experiment about geothermy was set up including learners from two locations with very different geothermal contexts: Guadeloupe and Quebec.

The West Indies arc is located at the boundary of the North American plate, the South American plate and the Caribbean plate. The islands are the result of North and South American plates subducting under the Caribbean plate at a rate of 19mm/year (Calais et al., 2002). The subduction is active since Eocene (-55 Ma) and is associated with an 850 kilometers volcanic arc, forming the islands known as the Lesser Antilles. The volcanic arc is a double arc (Figure 1), with two distinctive branches in the northern part and a unique one in the southern part, starting from Dominica. In the north, the eastern part of the arc, also known as the extern or ancient branch is formed with old volcanoes and includes the islands of Marie-Galante, Grande-Terre of Guadeloupe, la Désirade, Antigua, Barbuda, St. Bartholomew, St. Martin, Tintamarre, Anguilla, Dog, and Sombrero. The rest of the archipelago (the southern and the northwestern part of the arc), includes the active and recent volcanoes, with Grenada, Grenadines, St. Vincent, St. Lucia, Martinique, Dominica, les Saintes, Basse-Terre of Guadeloupe, Montserrat, Redonda, Nevis, St. Kitts, St. Eustatius, and Saba (Bouysse, 1984).

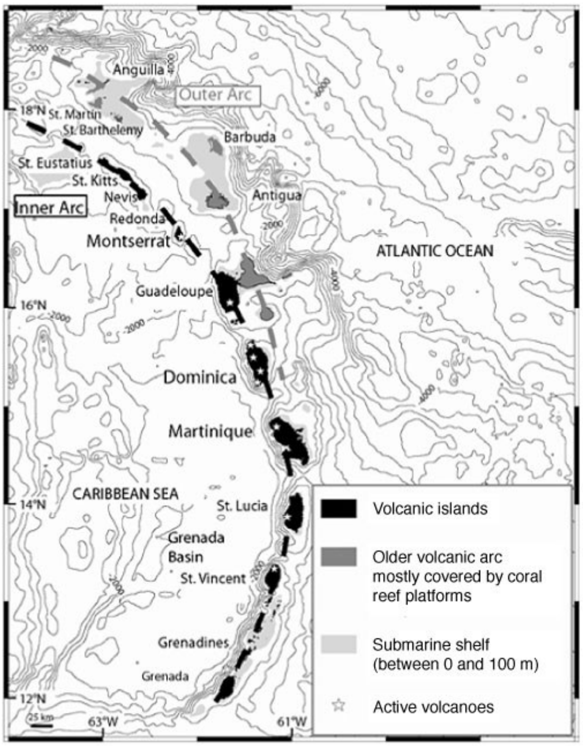

Figure 1: Volcanic arcs of the Lesser Antilles (Smith & Sandwell, 1997).

The geodynamical activity and geological context of the inner arc create a potential for geothermal exploitation in this area. In Guadeloupe, the Bouillante geothermal field has been exploited since 1984 and today provides about 8% of the local demand for electricity. The resource is located in the western part of the island, which is on an ancient volcanic system (Samper, Quidelleur, Lahitte, & Mollex, 2007) and on the Montserrat fault, allowing the reservoir to have a good fluid circulation. On this island the major part of energy and electricity is produced with oil importation and combustion (Observatoire Régional de l'Energie et du Climat, 2017). The development of renewable energies in Guadeloupe is an important environmental issue but is also an economic issue because Guadeloupe has the potential to become energy autonomous. Guadeloupe, therefore, is a good choice and opportunity for geothermal studies of science education and social acceptability. The Geotref Project supports this study and its objectives is to improve the knowledge and the technologies about geothermal energy and to develop the industry in the area.

In contrast, the geological context of Quebec is very different. The geological history of Canada, where some of the oldest igneous rocks on Earth can be found, began four billion years ago during the Archean. The dislocation of the Rodinia supercontinent (-1000 Ma) and of the Pangea (-100 Ma), has structured the northern part of the continent with what we call the Canadian shield in the central part, bounded, on the west side, by the Rockies and, on the East side, by the Appalachians and the Saint Lawrence Platform. In Quebec, in the eastern part of Canada, there are three major geological regions: (1) the great petrographic plains of the Canadian Shield, with the Province of the Superior, the Nain, Churchill and Grenville, mainly Archean and Proterozoic, (2) the Appalachian Mountains in southern Quebec mainly Paleozoic, and (3) the Saint Lawrence Platform, between both, mainly Paleozoic as well (Figure 2). The province of Quebec has a complex geological history. As a consequence, an important variety of rock types, rock ages and landscapes can be found. Montreal City is located on the lowlands of the Saint Lawrence Platform, that are mainly composed of sedimentary rocks of the Cambrian to Devonian period (Bourque & Université de Laval, 1997-2004).

The geological and geodynamical context of Quebec does not provide such accessible resources for geothermal electric production, as it does in Guadeloupe. Moreover, the major part of electricity in the province (about 93%) comes from hydroelectricity, so there is no such need as in Guadeloupe for renewable energy development. Nevertheless, the possibilities of exploiting geothermal energy for electricity using the potential of very deep reservoir or with alternative methods such as EGS (Enhanced Geothermal System) is currently focusing studies (Richard et al., 2016). In addition, extreme temperature variations due to the climate makes the exploitation of low temperature geothermal energy very useful. In fact, as the ground temperatures at a shallow depth are relatively constant, it can be used as energy supplement for heating in winter and air conditioning in summer, at a house or neighborhood scale.

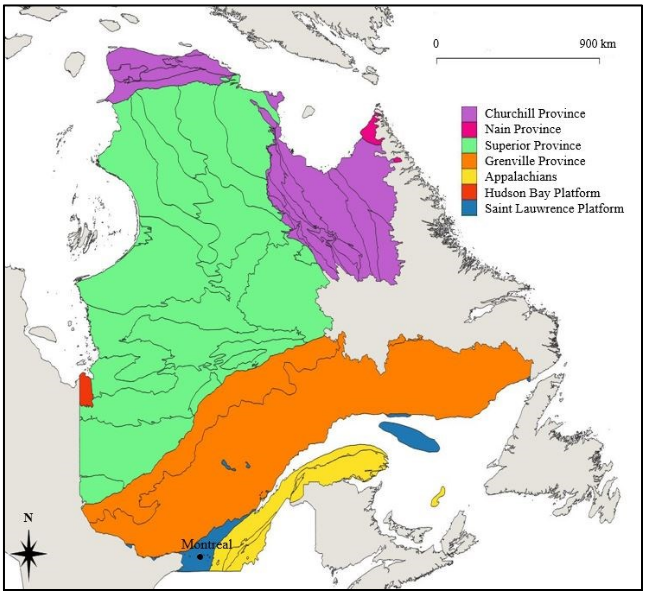

Figure 2: Geological map of the province of Quebec.

2. THEORETICAL FRAMEWORK

2.1 Relationships between Contexts and Conceptions

The term "context" is unfixed and difficult to define because it can be used in various disciplines and has a meaning for each of them. In science education, context is often defined as an external factor to learning. It can be associated to the institutional constraints on the relationships between teachers and students (Sauvage Luntadi & Tupin, 2012). In sociology of education, context can affect the behavior of an individual (Loria, 2017). It can take the form of relationships between contextual and individual parameters that influence school success (Duru-Bellat & Mingat, 1988). In language education (Blanchet, Moore, & Asselah Rahal, 2009), the context is made up of the learners' mastery of languages and of the teacher's ability to adapt his teaching. It can also be a factor that influences the meaning of a verbatim. In science education, "context-based approaches" (King, 2012) focus on students' natural contexts as a motivating element. These approaches allow authentic and stimulating teachings (Schwartz, Lederman, & Crawford, 2004). A contextual pedagogical approach, in science education, emphasizes the application of science as a means to improve students' scientific understanding of the real world, while developing their abilities to function as responsible actors in their daily lives (Bennett, 2005).

The relationships between context and cognition, according to Bazire and Brézillon (2005), identifies the context as being internal or external nature. In the first case, it belongs to an individual and occupies a main place in the representation that the individual constructs of the situation in which he is involved. The external context is related to elements external to the individual. This correlation between the context of an individual and his representations of what surrounds him illustrates the theories of internal context and external context defined by Van Wissen, Kamphorst, and Van Eijk (2013). They define the external context of an individual as all that surrounds and interacts with him, and the internal context as the individual mental representation of a given object or concept. The two notions are closely linked because the external context of an individual participates in the construction of its internal context.

2.2 Context Effects Pedagogical Approach

According to Delcroix, Forissier, and Anciaux (2013), the term "contexts effects" is derived from an analogy with Brousseau's "contract effect" (Brousseau, 1980). Contexts effects manifest themselves when there is a gap between a teaching or learning objective and its realization and are qualified in this way when the gap is attributed to the different contexts involved in the didactic process. This concurs with Sauvage Luntadi and Tupin's idea, that the school environment or the didactic context has an impact on the supposed learning and on the acquired knowledge (Sauvage Luntadi & Tupin, 2012). The emphasis here is on the gap between the knowledge taught and the acquired knowledge. According to Forissier (2015) a contexts effect is the manifestation of a conceptual shift related to the different internal contexts of two actors (subjects carrying conceptions) during a didactic interaction.

As stated by Acioly-Regnier and Regnier (2005), learning in contexts can generate obstacles that will influence the conceptual development. The creation of situations in which learners are confronted to different representations of an object can generate socio-cognitive conflicts associated to obstacles. Overcoming the obstacles provides the students with a motivation that helps them learn. The implementation of a pedagogical design based on contexts effects can be a support for the learning, by jostling students' initial conceptions. Contexts effects can generate cognitive shock and be used in the teaching as a lever for learning.

On the one hand, the use of context, a learner environment, in a didactic situation, can be a tool for authentic teachings. In the teaching of geology, the field is a natural support for the understanding of the concepts and their scale (Orange, Beorchia, Ducrocq, & Orange, 1999; Sanchez, Prieur, & Devallois, 2004). On the other hand, learners' conceptions, if they are not considered, can be barriers to learning. Considering the internal context of a learner can be a crucial resource for teaching. The confrontation between the internal context and the external context can generate a cognitive conflict. For example, observing the moon in Guadeloupe can lead to the emergence of a context effect if the learner's representation is a vertical crescent while its observation is a horizontal one. The effect provoked can be at the source of a questioning: Why is the crescent horizontal? This will require a deeper questioning and motivate the learner to understand the phenomenon. Explanations of the phases of the moon, which are concepts discussed in primary school, uses models that do not take into account latitudes (Delcroix et al., 2013). The context effect here can be the starting point to the explanation of the moon phases and of its orientation and so be a tool for the diversified knowledge acquisition. The internal context can also generate context effects, when confronted with the internal context of another person. If two individuals with different conceptions of an object of study share their conceptions and interact, then, contexts effects can emerge. Differences in external contexts can be responsible for differences in learners' conceptions. The prior identification of two external context deviations for a studied object may predict the emergence of context effects between learners from those two contexts.

A previous experiment in the field of biology (Fécil, 2014) has shown that context effects can take the form of surprising actions during field investigation, leading students to realize by themselves that their conceptions are erroneous. It is the type of contexts effect opposing the observed reality and a representation of the studied object. The experiment has also shown that contexts effects can emerge during exchanges between students with very different conceptions, and then create clashes (Forissier, Bourdeau, Mazabraud, & Nkambou, 2013) of representations that can lead to the emergence of emotions. Thus, a context-based teaching must involve two crucial phases: an inquiry-in-context approach to anchor students' conceptions in the context, and interactions with students from another context in order to provoke a clash of contexts and highlight effects of contexts.

2.3 Modelling Contexts Effects

To better understand contexts effects, and to predict the probability of their occurrences, a computational model of a context-gap calculator was developed (Anjou et al., 2017), in order to capture and evaluate differences amongst contexts. This approach assumes that the greater the differences in the contexts being studied are, the stronger the context effect is likely to be in the experiment. The first step of the study was to characterize as much as possible each context. To do so, the context had to be studied on different scales (geographical, temporal, and social). The integration of the observations at each relevant scale allowed for the modelling of the context. Once the two contexts used in the experiment are well defined, it is possible to calculate context-gaps (difference between both contexts) and to create pedagogical scenarios based on contexts effects.

3. METHODOLOGY

The execution of the experimentation requires a pedagogical design adapted for both geothermal contexts, in Quebec and in Guadeloupe. Geothermal energy can be perceived very differently depending on its geographical location, and it can be defined according to the geodynamic, geology and general geoscientific aspects. Its perception is also influenced by political, economic and industrial factors. In order to measure the gaps between the two geothermal contexts, the modeling of the so-called contexts has been realized allowing a gap calculation. The calculation results provide teachers with a support for the creation of pedagogical scenarios, shared in both locations, allowing for the emergence of contexts effects phenomena.

First, a modeling tool and the results of the gap calculation will be presented. Then, the pedagogical experiment methodology, its' organization, the collected data and the analyses undertaken, will be explained.

3.1 Modeling Context for Teachers' Support

The contexts calculator is a numeric tool that compares two models of an object in different contexts. It allows to calculate the differences between the object modeled in two contexts and to provide information about object's parameters susceptible to enable the emergence of contexts effects. The object considered in the experiment is geothermy in both Guadeloupe and Quebec. The object model uses a set of parameters to which is associated a value that may be different according to the context. In order to calculate the differences between the two contexts, properties are attributed to the parameters that define the rules applied for the calculation. For example, a parameter with nominal variables "type of energy produced" will not have the same calculation rule as that of the "age of the geological layer in which geothermal in exploited" which have ordinal variables.

For the purpose of the experiment, and in accordance with the Design-Based-Research methodology, the tool used for the gap calculation was a prototype, created with the Excel software. The differences highlighted by the calculator can be presented for a domain: geology, environment (Figure 3), or for each parameter, or others type of parameters gathering, like for example, geological scales.

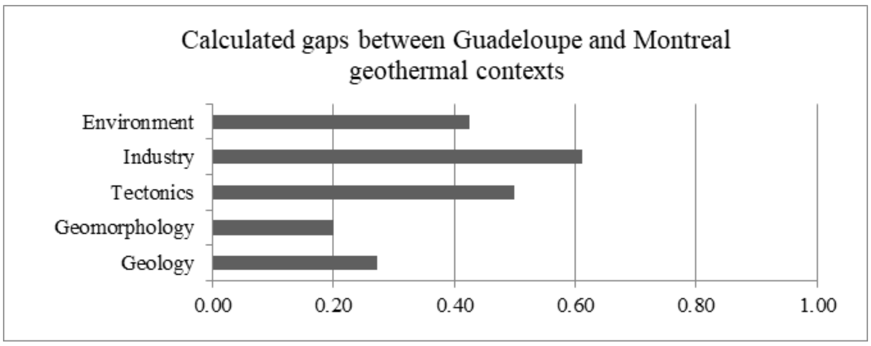

Figure 3: Calculated gaps synthesis between Guadeloupe and Montreal geothermal contexts (with 0 = no difference and 1 = fully different).

With this information, teachers can shape a pedagogical scenario that will allow the emergence of the predicted contexts effects. They will also be able to influence the running of the pedagogy, for example: during the inquiry phases, or with a stimulus during the teams' interactions, in order to provoke context effect.

3.2 The experiment

3.2.1 Organization of the Experiment

Two classes of students in a teacher training formation were involved in the experimentation. In Guadeloupe, it was a class of 12 students from Université des Antilles and in Québec, a class of 26 students from the UQAM (Université du Québec à Montréal). The experiment lasted from January 3rd to April 6th, 2016.

The pedagogical organization was to foster and promote the emergence of contexts effects. Therefore, communications and context-based inquiries were set up. This pedagogy was drawn from the Jigsaw method (Aronson, 1978). Students were committed to a common investigative process that focused on the implantation of a company willing to use geothermal energy as a complement for the cooling of server rooms and hardware. Students had to work together to find the best place in Guadeloupe and in Quebec for the implantation of the company, by studying the contexts' characteristics.

The pedagogical scenario had four distinct phases (Figure 4). Students were organized in two groups (one in Guadeloupe and one in Quebec) and groups were comprised of small teams. Every team group had its corresponding team in the other group, with which communications and collaborations were set up. The arrows indicate the interactions.

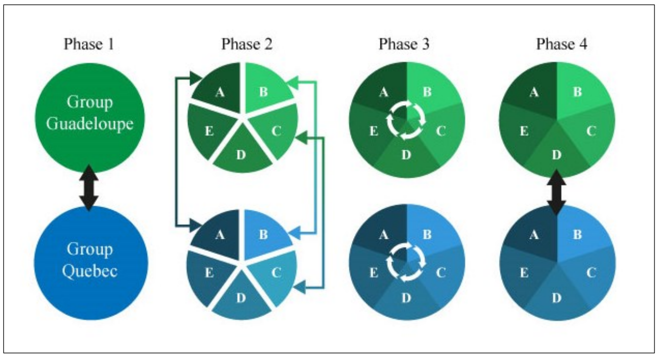

Figure 4: Pedagogical organization of interactions.

The first phase only lasted one session. During this session, the common pedagogical scenario was presented, and students organized themselves into five teams per group with one common theme for the corresponding teams of each group. To that end, a videoconference between the two groups was arranged, allowing for a debate moderated by the teachers.

The second phase ran for several sessions. During these sessions, every team investigated its theme in its own context. Then, videoconferences were settled between every corresponding team in order to let the students exchange their ideas and areas of investigation. These exchanges led the students to understand the context of the corresponding team. The objective was to provide them with new avenues of research, perhaps more global, but that could be applied in different contexts. Contexts effects were expected to be recorded in this phase.

During the third phase, all the teams belonging to one group worked together. The results of each team were integrated in order to build a common answer to the initial global problem in both contexts. The answer needed to include the data of each team in the same group. The results were restored via an oral presentation for the group.

During the fourth phase, each group presented its overall results during a videoconference bringing together the two groups.

3.2.2 Collected Data

Two types of data were collected during the experiment. Pre-test and post-test questionnaires were used in order to document students' conceptual changes, and interactions between students from the two contexts were video recorded, to observe and study the contexts effects.

Questionnaires:

The questionnaire was submitted to the students before the experiment, and after. This allowed the gathering of conceptions before and after the teaching. It included twenty questions: fourteen questions about geothermal energy (ten open-ended, two drawings and two multiple choices questions) and six questions about individual identification (social and personal background).

For the questions dealing with students' knowledge about geothermal energy, data was processed based on two dimensions: the contextuality and the expertise. The first dimension opposes contextual to acontextual answers. The modeling tool used to calculate context's gaps allowed the identification of very different elements about geothermal in Guadeloupe and in Quebec. It also allowed the detection of notions only present in one of both contexts. If such notions are quoted, and quoted alone, the answer is considered as contextual. But if the answers contain elements related to both contexts or none, the answer is considered acontextual. For the expertise dimension, processing opposes naïve answers to expert ones. The answer is considered as naïve if it refers to concepts that are not directly linked to geothermal or if it uses an informal language. Answers are considered as expert if it is linked with scientific knowledge and uses a technical vocabulary referring to complex scientific concepts.

Table 1: Pre and post-test questionnaire description with questions processing (open-ended questions).

Open-ended question about geothermal		Modality 1	Modality 2	Modality 3	Modality 4	Modality 5
1	Quote five words related to geothermal.	Naïve acontextual words	Naïve contextual words	Expert contextual words	Expert acontextual words	Irrelevant words
2	How do you explain the natural geoscientific phenomenon of geothermal?	Naïve acontextual	Naïve contextual	Expert contextual	Expert acontextual	No answer
2b	Illustrate it with a diagram.					
3	What does a geothermal exploitation produce?	Contextual	Acontextual	No answer		
4	Where can a geothermal resource be found?	Naïve acontextual	Contextual	Expert acontextual	No answer	
5	At what deep can geothermal energy be exploits?					
8	Make a captioned diagram of a geothermal exploitation	Naïve acontextual	Naïve contextual	Expert contextual	Expert acontextual	No answer
9	Do you think geothermal energy contributes to sustainable development?	Yes	Mixed opinion	No	No answer	
10	What is your view about this concept?	Rather pro	Mixed opinion	Rather against	No answer	
11	What are the proportions of renewable / non-renewable energy in your country?	More non-renewable energies	Same both	More renewable energies	No answer	
12	Do you think geothermal is lucrative?	Yes	No	No answer		
13	Have you ever been confronted with geothermal energy or exploitation?					

Table 2: Pre and post-test questionnaire description of multiple-choice questions.

Multiple-choice questions: modality 1 (box checked) or modality 0 (box unchecked)				
6	Check words that belong to the field of geothermal.	Forest	Snow	Energy
		Pump	Radioactivity	CO_2
		Turbine	Fire	Heat
		Oil	Hot	Air-conditioning
		Drilling	Cold	Climate
		Gaz	Magma	Isolation
		Aquifer	Wind turbine	Rain
		Volcano	Sun	Steam
7	Check the phenomena linked to geothermal concept.	Thermodynamics	Radiation	Heat flux
		Conduction	Precipitation	Magmatism
		Convection	Seismic	Ionization

Table 3: Pre and post-test questionnaire description with questions processing for identification questions.

Questions about identification	Modality 1	Modality 2	Modality 3	Modality 4
Gender	Male	Female	No answer	
Age	< 30 y o	> 30 y o	No answer	
Origin	Antilles	Canada	Other	
Higher education speciality	Sciences	Biology	Other	
Professional activities	Yes	Non	No answer	
Qualifications	Bachelor	Master	PhD	No answer

A total of 61 questionnaires was collected (pre-test and post-test), and was structured in 4 cohorts:

- 1st cohort: students from Guadeloupe, pre-test (12 individuals);
- 2nd cohort: students from Quebec, pre-test (23 individuals);
- 3rd cohort: students from Guadeloupe, post-test (8 individuals, 7 from the 1st cohort and 1 new one);
- 4th cohort: students from Quebec, post-test (18 individuals, 17 from the 2nd cohort and 2 new ones);

The collected data were analysed with the statistic method: descriptive analyses and multiple correspondence analyses.

Video Recordings:

The data collection provided six video recordings from exchanges between the corresponding teams. The total length is 95 minutes. The objective is to identify contexts effects moments. To this end, the recordings only concern interactions between corresponding teams (phase 2). Previous studies about contexts effects have shown that they often result in students' awareness of a lag between their conceptions. Physical behaviour and exchanges' contents have been analysed. The processing methodology was carried out at two levels: processing based on the audio, with the exchanges' contents and also intonation, speech rate, pauses or interjections (verbal and para-verbal analysis), and a visual processing based on facial expressions, gestures and postures (non-verbal analysis).

4. DATA ANALYTICS AND RESULTS PRESENTATION

4.1 Pre and Post-Test Questionnaires

In order to illustrate the results obtained after the questionnaire analysis, the first question will be detailed.

A total of 59 individuals answered the question and 298 words were collected in pre and post-test, in Guadeloupe and in Montreal. Each word was analysed depending on the cohort to which belongs the student who has enunciate it and depending on the two dimensions defined earlier (contextuality et expertise). This treatment gave rise to five categories of words:

- acontextual naïve words (type 1);
- contextual naïve words (type 2);
- acontextual expert words (type 3);
- contextual expert words (type 4);
- off topic (type 5).

The table below shows the quantitative repartition of words according to the modalities.

Table 4: Number of words by cohort and by type.

Q1	Type 1	Type 2	Type 3	Type 4	Type 5	Total of words by cohort
Cohort 1	29	9	6	13	0	57
Cohort 2	82	3	5	13	8	111
Cohort 3	11	5	6	18	0	40
Cohort 4	49	5	16	19	1	90
Number of occurrences by category	171	22	33	63	9	Total number of words: 298

No answers: one student from cohort 2, and one student from cohort 4

In Guadeloupe, according to Figure 5, 51% of the collected words in pre-test are naïve and acontextual, referring to very general geothermal concepts and to an everyday vocabulary. In the post-test, 45% of the words are expert and acontextual. In general, there is an increase of expert words between the pre-test and the post-test (34% in pre-test against 60% in post-test). This progression is the only significant one because in a smaller cohort there are more expert words. Moreover, the decrease in the number of naïve words is so important that it cannot be due to the cohort change. The proportion of contextual words is still quite the same between the pre and post-test (27% in pre-test and 28% in post-test).

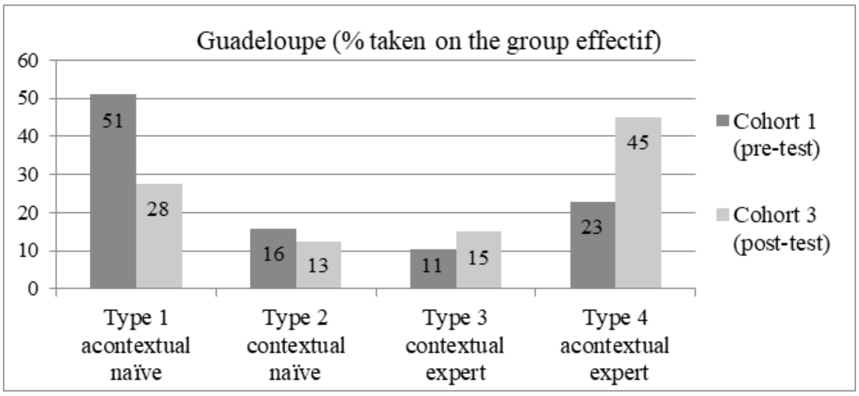

Figure 5: Type of word percentage in pre-test and post-test in Guadeloupe.

In Montreal, Figure 6 shows that 74% of words in the pre-test come from an everyday vocabulary and are not specifically linked to the geothermal context of Quebec. In the post test, 54% of the collected words belong to this category. A decrease for this word category was noted. For the contextual dimension a 16% increase was observed between the pre-test and the post-test (8% in the pre-test and 24% in the post-test). A 22% increase was also observed for the expert dimension between the two tests (17% of expert words in the pre-test and 39% in the post-test). In Montreal, there are changes in students' answers according to the two dimensions but only the expertise dimension increase is significant.

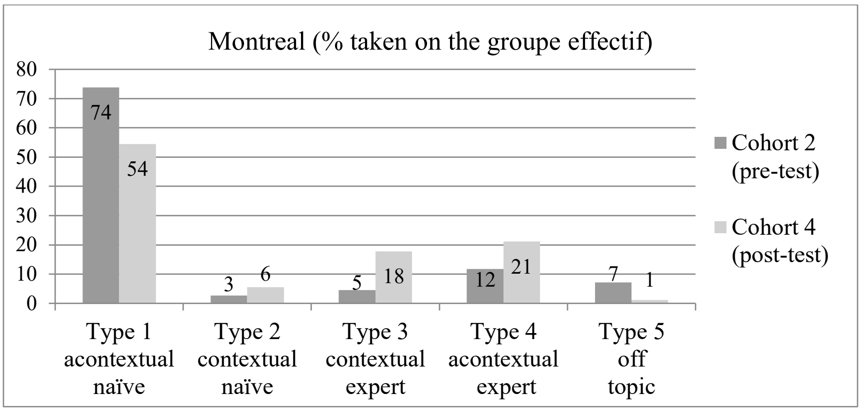

Figure 6: Type of word percentage in pre-test and post-test in Montreal.

With the pre-test and post-test analysis it was possible to follow the evolution of the learners' conceptions, by questioning their knowledge and their opinions. Knowledge was analysed according to two dimensions: contextuality and expertise, and opinion, depending on whether learners are favourable or unfavourable to the development of geothermal energy. For all knowledge questions, an increase in expert responses after experimentation was observed. This means that students have acquired expert knowledge, different from their previous spontaneous knowledge. For these questions, a decrease in naïve knowledge was also observed, however, this observation is not significant due to the number of absentees in post-test.

In terms of contextuality, again, for the knowledge questions the comparison was more delicate. Nevertheless, it seems that in the Montreal group, the acontextual responses increased after the training and the contextual responses decrease. The decrease of answers can hardly be attributed to an evolution of conceptions, because of the number of students absent in the post-test. In Guadeloupe, the evolution is different. In general, the amount of contextual responses seemed to increase in the post-test. It is interesting to note that conceptions of contextuality do not evolve in the same way between the two territories, even though the pedagogical scenario was similar.

4.2 Videos Recordings

The 95 minutes of video recordings between Guadeloupean and Quebecois students were analysed with the verbal, para-verbal and non-verbal methods. In order to illustrate the video analyses, one will be summarised. The video selected was recorded during an interaction between two teams, one in Montreal and one in Guadeloupe, working on a way to bring cold air to the computer server room and to study the environmental impact of it. For about 20 minutes, the Montreal team tried to explain that they wanted to take cold water from a lake and to use it to cool down the room, and then put the water back in the lake, like an open circuit. During this long moment, we observed that the conceptions of Guadeloupe students about geothermal energy, that it is something hot, is so engrained that they could not understand the Montreal team and the idea of taking cold: "So the application of your model is for the heating of a house ?", "Is It for the heating in winter ?". At the end of the exchange, the conversation went on about the exploited water temperature. The Montreal team revealed that the water temperature they wanted to use is around 4°C. This dialogue generated the spreading of hilarity in the two teams, caused by the differences between the temperatures of hydrographic systems in Guadeloupe and Quebec. This was interpreted as a contexts effect.

In all of the videos, identified contexts effects were linked to different concepts, and different contexts gaps. The following are some examples of contexts gaps that were highlighted during the students' interactions: the climate: because the soil is covered with snow in Montreal in winter, students cannot take samples of soil; the environment: hot water discharged in the sea linked to rum production can serve as an example for the study of hot water discharges impacts on the marine fauna and flora; the energy industry: in Montreal, mainly hydroelectric dams produce electricity so the geothermal energy production is not such an important issue as it is in Guadeloupe; volcanology: there are no active volcanoes in Quebec; pedagogy: in light of these differences, the pedagogical approaches are perceived differently by students in Guadeloupe and in Montreal.

These contexts gaps found in the videos are often associated with behavioural changes or contagious emotional reactions within the teams, like hilarity, surprise, excitement but also frustration, disinterest or disappointment.

We interpret these behavioural and emotional changes as the physical response to a cognitive reaction and can be associated to contexts effects' markers. Those transformations can be very brief or can last some time, they can be very explicit or more subtle and hard to detect (more or less intense). The changes can affect one or more actors of the interaction and can be managed in different ways (it can be ignored or shared and deepened). Finally, the contexts effects can have a positive or a negative impact on the interaction. All those characteristics of the contexts effect can affect the learning in different ways and generate motivation and active learning.

5. DISCUSSION AND CONCLUSION

The evolution of students' conceptions was described through the use of multiple questionnaires analyses (descriptive and multiple correspondence analyses), according to two dimensions: contextuality and expertise. An increase in expert answers was observed for Guadeloupe and Montreal in the post-test. In comparison with their initial conceptions, it was noted that students acquired more expert knowledge. It was also observed that there was a decrease in naïve knowledge. Concerning the dimension of contextuality, the evolution was not the same in Guadeloupe and in Montreal. In Montreal, acontextual answers increased and contextual answers decreased whereas in Guadeloupe, the number of contextual answers seemed to increase. This variation in the evolution of conceptions may have been caused by several factors, the first one being the geothermal context. In Montreal, geothermal energy is mainly used for temperature regulation in buildings and there are many museums and cultural centres (Biosphere, Biodome, the House of sustainable development) that use it and they have diffused this information. There are also projects for the exploitation of high temperature geothermal energy in former mines or in the Saint-Lawrence Lowlands, where it is possible to associate it with carbon storage. These projects are less known, but they could lead to conceptions, in Montreal, and be more easily associated with those different aspects of geothermal energy. It is expected that the geothermal notion in Montreal could be described in a non-contextual way and could refer to various types of geothermal energy or a global and phenomenological definition of it. It is also possible that the inquiries conducted into the context by students in Montreal lead them to widen their knowledge, because of the geothermal diversity of Quebec. In Guadeloupe, the geothermal context is very different. Guadeloupe is the only island of the West Indies that currently produces geothermal energy. It is a crucial importance for the economic and energetical development of the island. Geothermal energy is rather well known by students in Guadeloupe thanks to the existence of the geothermal power plant in Bouillante. Naturally, students' conceptions are built according to that geothermal type. Moreover, the contextual inquiry conducted during the experiments was probably set up in relation with those pre-conceptions. Students in Guadeloupe have thus developed their contextual conceptions.

The difference into the conception's evolution in Guadeloupe and in Montreal might also be caused by the didactic situation. The pedagogical organisation in Quebec and in France are very different on many levels. In Quebec, the teaching session was about teacher training in "Sciences and Technologies", whereas in Guadeloupe it was teachers' training in "Life and Earth Sciences". The transmitted conceptions of sciences might not be the same in the two countries. In Montreal, students are evaluated on the production of a pedagogical scenario integrating a technological aspect (experience or model). In Guadeloupe, the objective was about the deep understanding of the geothermal concept. The fact that pedagogical activities might have been approached differently by students could be a factor influencing the evolution of conceptions.

The scientific literature shows that context effects are very present in education, in various disciplines. The objective of this study was to show that contexts gaps can be used for teaching and can even be a resource. With the pre and post-questionnaires, it can be established that the conceptions in Guadeloupe and in Montreal before the experiment were very different. These differences created an ideal situation for a pedagogy with contexts effects to emerge. Interactions between students allowed for the confrontation of conceptions and sometimes created obstacles for mutual comprehension and learning. However, even if conceptual changes in students' conceptions associated to the learning were observed, it cannot be ascertained that the contexts effects pedagogy is responsible for this, and therefore, it is not possible to make a link between the learning and the students' interactions. Special care is needed in the pedagogical scenario creation in order to allow real collaborations and debates between students. With an adapted scenario, the contexts effects pedagogical approach could create authentic and active learning of the concept in various contexts.

ACKNOWLEDGEMENTS

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

Acioly-Regnier, N. & Regnier, J.-C. (2005). *Repérage d'obstacles didactiques et socioculturels au travers de l'ASI des données issues d'un questionnaire.* Paper presented at the Troisième Rencontre Internationale ASI, Analyse Statistique Implicative.

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

Anjou, C., Forissier, T., Bourdeau, J., Mazabraud, Y., Nkambou, R., & Fournier, F. (2017). *Elaborating the Context Calculator: A Design Experiment in Geothermy.* Paper presented at the International and Interdisciplinary Conference on Modeling and Using Context.

Aronson, E. (1978). The jigsaw classroom. Retrieved from https://www.jigsaw.org

Bazire, M., & Brézillon, P. (2005). Understanding Context Before Using It. In A. Dey, B. Kokinov, D. Leake, & R. Turner (Eds.), *Modeling and Using Context: 5th International and Interdisciplinary Conference, CONTEXT 2005, Paris, France, July 5-8, 2005. Proceedings* (pp. 29-40). Berlin, Heidelberg: Springer Berlin Heidelberg.

Bennett, J. (2005). *Bringing science to life: The research evidence on teaching science in context*: University of York, Department of Educational Studies.

Blanchet, P., Moore, D., & Asselah Rahal, S. (2009). Perspectives pour une didactique des langues contextualisée. *The Modern Language Journal, 93*(2).

Bourque, P.-A. & Université de Laval. (1997-2004). Planète Terre. Retrieved from http://www2.ggl.ulaval.ca/personnel/bourque/s5/5.1.carte.geol.quebec.html

Bouysse, P. (1984). The lesser antilles island-arc-structure and geodynamic evolution. *Initial Reports of the Deep Sea Drilling Project, 78*(AUG), 83-103.

Brousseau, G. (1980). L'échec et le contrat. *Recherches, 41*, 177-182.

Calais, E., Mazabraud, Y., Mercier de Lépinay, B., Mann, P., Mattioli, G., & Jansma, P. (2002). Strain partitioning and fault slip rates in the northeastern Caribbean from GPS measurements. *Geophysical Research Letters, 29*(18), 3-1-3-4.

Delcroix, A., Forissier, T., & Anciaux, F. (2013). Vers un cadre d'analyse opérationnel des phénomènes de contextualisation didactique. In F. Anciaux, T. Forissier, & L. F. Prudent (Eds.), *Contextualisation didactiques : Approches théoriques* (pp. 141-188): L'Harmattan.

Duru-Bellat, M., & Mingat, A. (1988). Le déroulement de la scolarité au collège: le contexte" fait des différences". *Revue française de sociologie*, 649-666.
Fécil, S. (2014). *Construire un enseignement en tenant compte des effets de contexte*. Mémoire. ESPE de Guadeloupe.
Forissier, T. (2015). Conceptions d'étudiants scientifiques de Guadeloupe sur l'observation de l'orientation de la lune et des saisons climatiques. In A. Delcroix, J.-Y. Cariou, H. Ferriere, & B. Jeannot-Fourcaud (Eds.), *Apprentissages, éducation, socialisation et contextualisation didactique: approches plurielles*: l'Harmattan.
Forissier, T., Bourdeau, J., Mazabraud, Y., & Nkambou, R. (2013). Modeling Context Effects in Science Learning: The CLASH Model. In P. Brézillon, P. Blackburn, & R. Dapoigny (Eds.), *Modeling and Using Context: 8th International and Interdisciplinary Conference, CONTEXT 2013, Annecy, France, October 28 -31, 2013, Proceedings* (pp. 330-335). Berlin, Heidelberg: Springer Berlin Heidelberg.
King, D. (2012). New perspectives on context-based chemistry education: Using a dialectical sociocultural approach to view teaching and learning. *Studies in Science Education, 48*(1), 51-87.
Loria, E. (2017). *The role of the ostensive communicative context in the childhood social learning.* Paper presented at the International and Interdisciplinary Conference on Modeling and Using Context.
National Research Council. (2000). *How people learn: Brain, mind, experience, and school: Expanded edition*: National Academies Press.
Observatoire Régional de l'Energie et du Climat. (2017). *Les chiffres clés de l'énergie en Guadeloupe, Bilan 2016*. Retrieved from
Orange, C., Beorchia, F., Ducrocq, P., & Orange, D. (1999). Reel de terrain", "reel de laboratoire" et construction de problèmes en sciences de la vie et de la terre. *Aster, 28*, 107-129.
Renouard, A., & Mazabraud, Y. (2018). Context-based learning for Inhibition of alternative conceptions: the next step forward in science education. *npj Science of Learning, 3*(1), 10.
Richard, M.-A., Giroux, B., Gosselin, L., Kendall, J., Malo, M., Mathieu-Potvin, F., . . . Raymond, J. (2016). Intégration de la géothermie profonde dans le portefeuille énergétique canadien. In: Hydro Québec, Institut de recherche.
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.
Sanchez, E., Prieur, M., & Devallois, D. (2004). L'enseignement de la géologie en classe de seconde: quels obstacles, quelles pratiques. *Actes XXVèmes JIES. Chamonix*.
Sauvage Luntadi, L., & Tupin, F. (2012). La compétence de contextualisation au cœur de la situation d'enseignement-apprentissage. *Phronesis, 1*(1), 102-117.
Schwartz, R., Lederman, N., & Crawford, B. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science education, 88*(4), 610-645.
Smith, W. H., & Sandwell, D. T. (1997). Global sea floor topography from satellite altimetry and ship depth soundings. *Science, 277*(5334), 1956-1962.
Van Wissen, A., Kamphorst, B., & Van Eijk, R. (2013). A constraint-based approach to context. In P. Brézillon, P. Blackburn, & R. Dapoigny (Eds.), *Modeling and Using Context* (Vol. 8175, pp. 171-184). Berlin, Heidelberg: Springer.