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COMPARING THE CONTEXTS TO UNDERSTAND SCIENCE

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Context-based science learning (CBL) creates instances for authentic inquiry pertaining to students' environment. It allows students to build their conceptions through interactions between a scientific model and an observable and specific example. In order to avoid the risk of building their conceptions from paradigmatic examples, this article presents research based on the contexts effects. reflecting the symposium*, principles and experimental modalities will be presented (part 1). One of the main results about context and conception lies in the fact that correspondences between the identified conceptions and the geothermal contexts of students have been established (part 2). In a design-based research, a modeling tool allowing to calculate contexts gap and predict contexts effects have been developed and* described (part 3). *The analysis of interactions and affective dimensions during presents the concept of contexts effect as a complex object both a psycho affective event (eureka effect) and as a constructed sequence of interaction (Contexts effect séquencies, part 4).*

Keywords: context effects, innovation in teaching/learning Modeling, Context gap Calculator, conceptions, geothermal energy, Collaborative Learning, Emotion.

The relationships between the students' natural and technical contexts and scientific learning were investigated in the context based framework context (King 2011). Context effect based learning is a collaborative method involving two groups of learners from different contexts with an inquiry process on a common issue. Each group discusses the involved concepts relating to examples in their context. Thanks to numerous distance collaborations, students work with their counterparts throughout the inquiry thus questioning their own conceptions as they are exposed to the other groups' conceptions. Everyone shares their culture, acquires digital skills and also disciplinary knowledge, of which the limits and possibilities are more precisely identified. The protocol, which has already been put into place during several iterations, is more effective if the contexts show clear differences.

The objective of this paper is to present learning based on the effects of contexts as a learning method but also to present various works related to these teachings.Several questions concerning learning based on the effects of contexts, are addressed. The first is the relationship between scientific conceptions and the contexts of a territory. The concept of context effect was initially defined as a cognitive break. This paper presents results from two different methodologies that centralize the socio-emotional and international dimension in order to show the complexity of this concept. How can we predict the appearance of a context effect? The part named "Development of a Modeling Tool for the Context Effects Based Teaching" presents the development of an external context deviation calculation tool. This tool is built on the assumption that the larger the external context deviations, the greater the chance of a context effect.

CONTEXT EFFECT BASED LEARNING, PRINCIPE AND EXPERIMENTAL MODALITIES

Context in Science Education

The emphasis placed on students' environment is an important factor in the teaching of Natural Sciences. Authentic learning experiences (Schwartz et al 2004) insist on the importance of teaching sciences within a framework of real investigation processes, thereby creating real problem-solving opportunities for students. In 2011, King, Winner and Ginns pursued this work by proposing a context effect based learning approach. The students' natural environment is the context emphasized in this study. It is the framework of their research which also enables the construction of contextual learning that is in close connection to the students' environment. The limit in this approach lies in the risk that students construct representations that are very contextualized, for which they are unaware of. Tardif, (1999) suggests viewing learning as a transfer between contextualized knowledge, de-contextualized knowledge and re-contextualized knowledge. This learning model resituates the relationship between learning and context with respect to the students' representation. Zimmermann & al (2004), links these two types of contexts under the terms internal (links to conceptions) and external (links to environment) and is interested in the relationships that can exist in instances of communication. This article proposes teaching methods in the science field, that will take into consideration external as well as internal contexts, while allowing students carrying out an inquiry in their external context to construct through their exchanges and collaboration on conceptions that are not limited to their contexts. A context effect is an event that arises during a teaching/learning relationship between two actors. If the effects of contexts were first presented as an obstacle to learning, the teachings described in this text aim to provoke them in order to express the different students' conceptions during collaboration.This event is related to the difference between their internal contexts. It may be expressed as different manifestations of emotions (laughter, conflict, incomprehension) and lead built more complex scientific conception.

Principles and design modalities in an iterative approach

Education based on the emergence of context effects has been put in place on several scientific themes. Knowing different observables between Guadeloupe and Quebec: the concept of adaptation of frogs (tropical arboreal or pond), fruit (i.e. apple and banana), agricultural production of sugar (maple syrup and cane sugar) and the exploitation of geothermal energy according to the geological contexts.These interactions have been of 2 or 3 months duration have allowed learners of primary, secondary and higher education to collaborate during scientific investigations. The results show different modes of emergence of context effects. These effects of contexts differ by the external contexts involved, by the moments of emergences during the inquiry and by the emergence modalities. Numerous learning has also been demonstrated, and expert representations appear.

Methodological issue

Design-Based Research (DBR) is a well-recognized methodology for its relevance in design projects of technological environments in education Anderson & Shattuck (2012). As its name indicates, it is inspired by the science of design, and is oriented towards the design of artifacts; it brings together theoretical concerns and field considerations for the development of solutions.

Inspired by Brown (1992), the founding works (Barab and Squire, 2004, Wang and Hannafin 2005), were quickly adapted to the questions of science education (Sandoval and Bell, 2004). The DBR has been built around two characteristics. The first is the twofold goal: the advancement of theoretical knowledge and the iterative conception of a solution, the two elements being considered as a single whole. The second characteristic is the in situ mode practiced both in terms of collaboration with the actors in the field and for the tests and micro-experiments conducted during the different phases.

The mixed methodology uses to collect data on each iteration include analyzing of texts produced by students, pre-test and post-test interviews, and videoconference recordings. The phenomenon of context effect has been described as a process of cognition expressed during interactive sequence with strong emotional dimension (incomprehension, surprise, satisfaction).

Principles and Learning scenario

In order to bring out a lot of context effect, a number of principles can be proposed: choosing students who can collaborate with each other, maximize external contexts opposition, allow students to develop contextual conceptions, compare its to conceptions build in a different context and then integrate it's to build a more complex conception, dependent on the contexts and more aware of the limits and generalities of the concepts. The modalities of the learning scenarios are based on these principles (table 1).

Table 1. Principles and learning scenario

Principles	Learning Scenario
Different external contexts	Objects of scientific study that are observable and part of the students' environment
Collaborative students: levels close but not necessarily identical	A common problem for all students
	Small work teams
	Students who can introduce themselves, meet
Buid contextual representations	Field investigation
	development of a particular methodology
	Writing a response proposal in each context
Confronting contextual representations	Multiplying moments of collaboration
	Alternate working moments in context and synchronous and asynchronous exchange times throughout the project
	Present findings synchronously to peer teams
Build together expert representations	Metacognitive phase and explanations of the representations of each other

Learning model and contextualized conception

Teaching that is based on the emergence of context effect is an innovative teaching method based on the collaboration between students carrying out field investigations in different contexts. In the examples studied. Many learning opportunities occurred and seem to be structured according to two axes. First, the students acquire specialty competencies while carrying out a study within their own context. Then, after a collaboration with the other teams from the other context, the students build expert responses that are characterized by a more complex approach with respect to concepts (diversity of situations) and a better description of the limits of these concepts. Those experiments also allowed observing and describing in-situ context effects.

The "CLASH" model used in these learning situations is based on a shock of internal contexts and gives a significant place to contexts in learning. This generic model was originally designed to be applied to environment learning. By placing students in inquiry, field observation, data collection, and then confronting them with the results of a peer team in a different context, these students are challenged when faced with differences in context for the same object of study.

In keeping with the concept of situated conception (Clément, 1999) wich is expressed according to the conjunctures, the conceptions in the natural sciences are also contextualized : they are constructed with respect to the observal nature by integrating the diversity studied environments. Hence the question of the uniqueness of a relation between a general model and a particular example derived from the epistemology of physics might not be optimal for understanding naturalistic concepts.

COGNITIVE ELEMENT ANALYSIS IN LEARNERS' DRAWINGS

Specific theoretical framework

Conceptions may correspond to a system of interactions between knowledge structures, value systems and social reference practices of individuals (Clément, 2010). The context-based approaches (King, Winner, & Ginns 2011) emphasize the importance of including learners' environment in teaching, in order to promote a better understanding of the world in which they live and also to improve their motivation. Context effects-based pedagogical approaches therefore insist that contexts and conceptions be an integral part of the learning process. In order to set up these approaches, it is necessary to clearly identify learners' initial conceptions, as well as contextual differences that may exist between various geographical areas, with respect to the studied object. The West Indies are volcanic islands resulting from the subduction of the North and South American plates under the Caribbean plate and they thus have significant geothermal activity. The involvement of local actors in the development of this energy industry presupposes its integration in education. The present study focuses on learners' conceptions in three Caribbean territories, that in spite of a relatively close geological context, present different geothermal contexts and uses of geothermal energy. In Guadeloupe, a geothermal power plant located in Bouillante city produce 8% of the island's electricity. In Dominica, despite a proven significant geothermal potential, 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. Our study aims to examine the relationship between learners' conceptions on a geothermal topic and the local contexts in which they are living. Furthermore, the study of geothermal energy is of interest in the field of science teaching since it is related to many general scientific and technological concepts such as energy, geology and technology.

Methods

A questionnaire survey was carried out in three islands of the West Indies (Guadeloupe, Dominica and Martinique) with a representative sample of 14-15 year-old students for a total of 1349 individuals (496 students in Guadeloupe, 372 in Dominica, and 481 in Martinique.) The questionnaire had several open-ended and closed-ended questions. Students were also asked to draw a geothermal power plant. In order to analyze those drawings, an initial list of 18 elements was first established. These elements, although directly referred to concepts related to geothermal energy, were also elements commonly found in drawings, even if they were not directly related to geothermal energy. Sometimes they were easily identifiable objects (volcanoes, crust, mantle or core, thermometer, etc.) or concepts that we believe contribute to a complete understanding of geothermal energy and its industrial production process (transformation, exchange, use or distribution). Coding was done according to the presence or absence of the elements in the drawings and some elements were regrouped, such as those related to renewable energy (wind turbines, solar panels, etc.). To avoid an errroneous analysis, a validation of the coding was carried out (Ehrlén. 2009).

Results

A descriptive analysis of the drawings reveals differences in students' views between the three islands. The most represented elements in the three islands are: ground, heat, tubes, and plants. In addition to these four elements, the most represented element in Martinique is: renewable energies, in Guadeloupe: transformation, and in Dominica: nuisance. Some drawings illustrating these specificities appear in Figure 1.

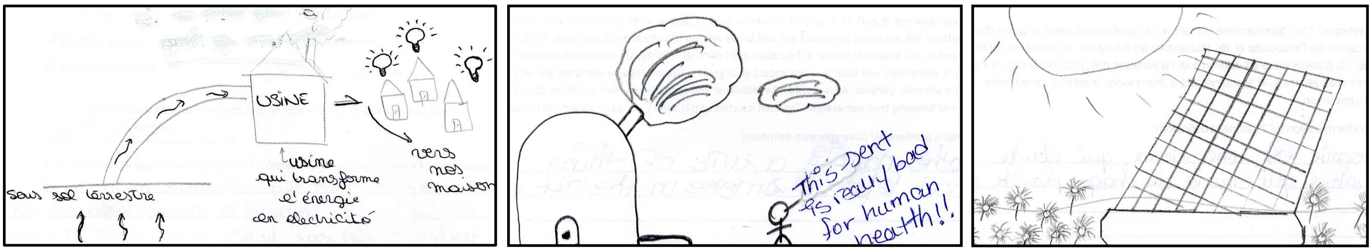

Figure 1. Examples of drawings from each island (from left to right: Guadeloupe, Dominique, Martinique).

Different methods, such as the Multiple Correspondence Analyses (MCA), were used (Figure 2): At the top left (in blue), are the grouped points corresponding to elements referring to renewable energy (wind turbine, solar panel, hydroelectricity…). Martinique is situated in this blue area. It is also very close to the "individual" element which is also represented in the drawings that illustrate individual uses in the form of heat or hot water. Guadeloupe is in the second zone (in orange), which groups together the elements that correspond to a representation of the soil, a plant, heat, nuisance, tubes, groundwater, a turbine, electricity and distribution. Guadeloupe students have a more industrial and technical perception of geothermal energy. They are also the ones who drew the most elements. Finally, the last zone (in green), includes the elements: earth, human, volcano and boreholes, as well as Dominica Island. The idea of human exploitation of a volcanic resource is well established in Dominica. According to this analysis, Martinique students have conceptions related to the environment and renewable energies, whereas Guadeloupe students' conceptions are related to industrial activity and Dominica students' conceptions are related mainly with respect to human exploitation of a volcanism resource.

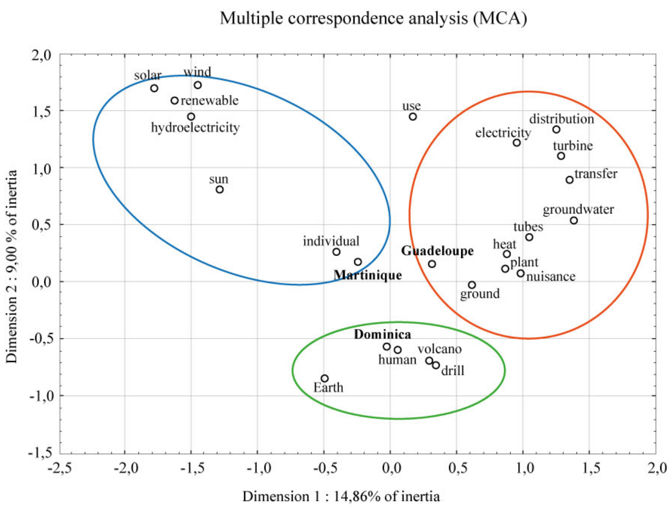

Figure 2 : MCA analysis between Guadeloupe, Martinique and Dominica

Observations from the analyses of the students' drawings highlight three main elements: (1) Very few students were able to include in their drawings more than two elements directly related to geothermal energy. This indicates a lack of knowledge in this area. (2) The MCA analysis reveals that conceptions are different depending on the island. (3) Others MCA analysis show that students from the same island have similar conceptions. In Guadeloupe, the presence of a geothermal power plant is well known by students. Conceptions are thus linked to the industrial aspect of the resource. In Dominica, despite efforts to exploit the resource in recent years, no facilities have been created. In addition, the media setbacks related to exploitation difficulties may have tarnished the image of this industry. The transcribed conceptions are related to the harmful aspect of the resource. Finally, in Martinique, because of the lack of geothermal facilities, students mainly describe the renewable aspect of the resource, and link it to the environment. These differences in learners' prior conceptions of geothermal energy are essential considerations. They can serve as a support for the setting up of pedagogies involving pupils from the three islands, such as those based on context effects.

ELABORATION OF A MODELING TOOL FOR THE CONTEXT EFFECTS BASED TEACHING

This part presents a research project in science education that is positioned at the intersection of computer science and context in learning. The main objective is to create a software tool that will participate, from the inception to the achievement, in the design of a leaning scenario, based on context effects. To this end, the software will allow to compute context differences between two learning environments. Input data include a chosen set of parameters, specific to the phenomenon or object that students are expected to explore in each learning context. The calculator has been elaborated according to the design based research theory. It is to be used in dynamic learning situations, with several iterations including field experiments, in order to collect comparable data in each context.

Specific theoretical framework

Our study focuses on the contextualization of science education involving fieldwork. Context is defined here as everything that surrounds an object and that has connections with it. Our main objective was to create a software tool, in order to support the design and development of context-sensitive tasks, inside a chosen learning scenario, by considering Context Effects (Forissier, Bourdeau, Mazabraud, & Nkambou, 2014). This software allows to provide several external contexts instantiations (Van Wissen, Kamphorst, & Van Eijk, 2013), in relation to the scientific object of study, and to compare them in order to predict the emergence of Context Effects. The software tool compares two geothermal learning contexts modeling, in order to highlight the points or concepts that show differences between the two contexts in that specific field. Using this comparison, one can bring to light significant differences and take advantage of them for the construction of a context-sensitive learning scenario. Learning is expected to happen more efficiently due to the gaps between contexts that may enrich learners' interactions within and between the two contexts. Our position is that context gaps during student's collaboration are what create context effects. Teaching based on context effects is an innovative approach in science education and allows students to develop rich and complete conceptions, and to open their minds to very different world contexts.

Methods

Taking into account contextual sensitivity in science teaching is important, especially if one targets inter-or trans-contextual educational activities. To enable this, we have designed a tool called Mazcalc which can be used when the object of the study is context sensitive. While using Mazcalc, the user is progressively led to model contexts and calculate their differences (context gaps) according to a built-in method. Four user profiles (four access levels) are supported, each related to a specific role: (1) cognitive computer scientist, (2) context and content modeling expert, (3) instructional designer, and (4) teacher. Each role has access to the appropriate tools to produce the resulting artifact: configured system and meta model (ontology), general and specific context models, context gaps and pedagogical scenario, and trans-contextual training activities.

A context is always defined with respect to the object of study. For this study, geothermy was used as the use-case for validating our tool. The object of study is represented by a model of context consisting of a set of parameters to which a variable is assigned, for each context modeled. The parameters have properties, which define the rules that will be applied for the gap calculation. They can be composite, dependent or independent (if they are composite, the parameter value assignation gives rise to a new parameter that, depending on the first one, can give rise to another composite parameter, forming a tree where values by level are weighted). Parameters' variables (ordinal or nominal) are either qualitative (fuzzy) or quantitative (numeric). They can also be continuous or discrete. Usually, a parameter is part of one or several groups of context parameters called, families.

The expert must first specify the relevant set of parameters of the object under study, whatever the context. As previously said, these parameters can be grouped into families and have scales (domain) of values that can be numeric or fuzzy. Once such a general model is specified, it can then be instantiated in one or more contexts (specific models). During the instantiation, the subset of the relevant parameters is determined and their values for the context are specified. It is possible to extend the subset of the parameters by adding new parameters specific to this context. It can follow a resolution that would include these local parameters in the model under certain conditions. The computation of the context gap is a process of alignment between two or more instances of context that highlights the differences between the parameters, and therefore the difference between the models. The calculation rules used vary according to the nature of parameters (variables and their current values). The overall result is viewable in several forms and can also be transmitted to a host system that uses Mazcalc services. The prototype was implemented as a user-friendly Web application leading to the current version of the tool (Psyché et al., 2018). An application programming interface (API) version of the tools is currently under development and will make it easier to connect Mazcalc services with any application where context-gap is to be considered. In the following section, we describe how the tool has been used for 'geothermal energy' as the object of study.

Context gaps computing for geothermal energy

In this section, we discuss how the Mazcal has been used for creating a context model of the geothermal energy concept, in Guadeloupe (French West Indies) and in Montreal (Quebec). The Caribbean Islands are located in a subduction zone, creating a great potential for geothermal energy. In Guadeloupe, this potential is harnessed, in Bouillante, and a geothermal power plant uses the groundwater heat. In northeastern America, the bedrock mainly consists of ancient Precambrian rocks from the Canadian Shield, which does not allow electricity production. There, the geothermal heat is used to regulate the temperature in buildings, to create spas and to grow crops. It is called low temperature geothermy.

We first specify a general context of geothermy by setting a number of relevant parameters into Mazcalc. Two specific context models are then created, making possible to easily compute context gaps between Quebec and Guadeloupe. Variables are assigned to the parameters, related to the expected context model for each context. The contexts gaps' values provided by the calculator can be plotted on a graph and provide a qualitative and quantitative support to teachers about what is different between the two contexts. They can thus be used as a support for the creation of pedagogical scenarios based on contexts effects. In fact context effects are expected to emerge during interactions between students in relation with the parameters for which gaps between the two contexts are important.

CONTEXT EFFECTS IN COLLABORATIVE LEARNING: VERBAL AND NON-VERBAL INDICATORS

In this part, we propose to analyze the interactive dimension of the manifestation of context effects in learning, focusing on both verbal and non-verbal indicators. In the following sections, we mainly analyzed between group verbal exchanges and within group affective dynamics to detect the so called "Eureka effect" happening when contrasting contexts induce debates and understanding.

Verbal indicators

« Collaboration is a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem » (Roschelle & Teasley, 1995, p. 70). Collaborative interactions concern ideas, representations, understanding and grounding (Schwarz & Baker, 2017). From this definition, researches on collaborative learning have investigated the role of communicative interactions to achieve a task and co-elaborate knowledge (Schwarz & Baker, 2017). Studies focus specifically on debate in which argumentation in interaction is engaged in order to answer a specific question by purely verbal means (Baker et al., 2007). Two main processes of creation of knowledge are associated with debate: the production of arguments or counter-arguments and the negotiation of meaning (Baker, 2002). According to this approach, we propose a model to analyze knowledge-building process in collaborative learning based on context effects.

We transcribed and analyzed several moments with a context effect on the TEEC corpus. We identified four steps on how knowledge is co-elaborated between groups in relation with a context effect (Figure 3). The context effect begins with a question asked by the teacher or by a learner (step 1). The question typically concerns knowledge and representations about concepts (e.g. functioning of a heat pump) that are necessary to pursue the common task. The question provokes debate where verbal indicators of context effect can be observed (step 2): comparison between the two contexts (e.g. "we use a heat pomp for that, you use it for that"), negotiation of meaning (e.g. "it is functioning like this because") or argumentation (e.g. "you are wrong, it is functioning like this"). The debate leads to the understanding of the difference between the two contexts (step 3). We observe a typical verbal expression as "ah, okay" or "ah, I understand" (e.g. "ah okay, it is because the temperature of the water is different"). There may have back and forth between the first three steps if the concept is not totally understood and/or if all the learners did not understand it. In such case, we observe learners who have understood the gap between the two contexts explain it to those who dit not understand it. This leads to the distribution of knowledge between learners and to the mutual understanding (step 4). Verbal indicators for mutual understanding are paraphrases and reformulations as well as expressions of a common approval (e.g. "we all agree to say that...").

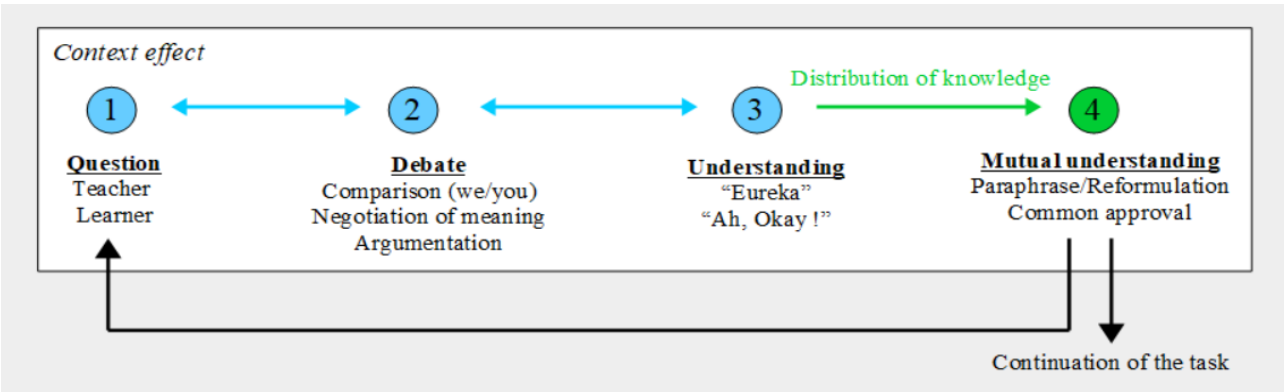

Figure 3. Model of the interactive dimension with context effect.

Non verbal cues

These last decades, affective computing has drawn more and more attention from many research communities: computer science, psychology, neuro-science, etc. It was defined as “computing that relates to, arises from, or influences emotions or other affective phenomena” (Picard, 1997). The general name of “socially aware computing” was introduced later (Pentland, 2005). In fact, there is more than words in social interactions: non-verbal behavior convey information about feelings, mental state, personality, and other traits of people. This happens through a wide spectrum of non-verbal behavioral cues like affective/cognitive states and conversational regulators.

A potential “Eureka effect” seems characterized by several affective states (and their corresponding cognitive states): (a) active listening or lack of understanding/frustration, (b) understanding/surprise followed by happiness and (c) mutual understanding (cognitive and emotional propagation). Figure 4 illustrates these three states. Of course, all these emotional states are more or less subtle due to the extravert/introvert disposition of learners. These information are collected by analyzing the internal dynamic of learner’s faces. But other cues (the so-called conversational regulators) can also be meaningful: (a) head pose (when learners turn toward each over) and mouth movements indicate potential turn taking, (b) head nod (resp. shake) indicates that learner agrees (resp. disagrees) with another one and (c) body movements can indicate either surprise or disengagement.

We use the following pipeline to extract low level information (i.e. faces and face poses, facial landmarks) and infer high level indicators (emotions and turn takings). We use *face_recognition* (Geitgey, 2016) to give an Id to each learner in the first image of the sequence. Then, we perform spatial face tracking throughout the sequence. We get 3D facial features, including face pose and facial landmarks using *PRNet* (Feng et al. 2018). We also use the latter to analyze who is talking and when in the video. Finally, we infer emotions using *Emotion-recognition* (Ayman, 2018).

Figure 4. “Eureka” effect. State 1: active listening. State 2: understanding. State 3: cognitive propagation.

At this point, the methods presented in this paper are under development, but several correlations have already appeared. In the next few months, we will use them to treat various corpus of data in order to refine them. We also plan to cross verbal and non-verbal analyses and deliver a global analysis tool.

CONCLUSION

At the end of this paper, contexts effects learning appears as an innovative method based on intercultural collaboration during comparison of the natural contexts of the students involved. It is technologically equipped with a context gap calculator. It provide knowledge on the close relationships between scientific concept and the natural contexts on the example of geothermal energy. The concept of contexts effect, originally defined as an event during conceptual changes, is today conceived through two other dimensions: a psycho-affective event (eureka effect) and a sequence of didactic interactions.

REFERENCES

Anderson, T. et Shattuck, J. (2012). Design-Based Research: A Decade of Progress in Education Research? *Educational researcher*, 41(1), 16-25.

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

Aronson, E., & Patnoe S. (2011). *Cooperation in the classroom: The jigsaw method (3rd ed.).* London: Pinter & Martin, Ltd.

Ayman O. (2018). Emotion-recognition. https://github.com/omar178/Emotion-recognition

Baker M.J. (2002) Argumentative interactions, discursive operations and learning to model in science. In P. Brna, M.J. Baker, K. Stenning & A. Tiberghien (Eds.) *The Role of Communication in Learning to Model* (pp. 303-324). Lawrence Erlbaum Associates, Mahwah N.J.

Baker, M.J., Andriessen, J., Lund, K., van Amelsvoort, M., & Quignard, M. (2007). Rainbow: A framework for analysing computer-mediated pedagogical debates. *International Journal of Computer-Supported Collaborative Learning*, *2*(2-3), 315-357.

Barab, S., Squire, K. (2004). Design based research: Putting a stake in the ground. *The Journal of the Learning Sciences*, 13(1): 1-14.

Brown, A.L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the Learning Sciences*, 2(2), 141-178.

Bourdeau, J. (2017). The DBR methodology for the study of context in learning. In *International and Interdisciplinary Conference on Modeling and Using Context* (pp. 541-553). Springer, Cham.

Clément, P. (1999). Situated conceptions. Theory and methodology. From the collection of data (on the brain) to the analyse of conceptions. In Méheut M. & Rebmann G.(éd), *Fourth European Science Education Summerschool: Theory, Methodology and Results of Research in Science Education*. U.Paris: ESERA, SOCRATES, p.298-315.

Clément, P. (2010). Conceptions, représentations sociales et modèle KVP. *Skholê : cahiers de la recherche et du développement*, *16*, 55-70.

Ehrlén, K. (2009). Drawings as representations of children's conceptions. *International Journal of Science Education, 31*(1), 41-57.

Feng, Y., Wu, F., Shao, X., Wang, Y., & Zhou, X. (2018). Joint 3D face reconstruction and dense alignment with position map regression network. In *European Conference on Computer Vision*, (pp 557-574), Springer.

Forissier, T., Bourdeau, J., Mazabraud, Y., & Nkambou, R. (2014). Computing the context effect for science learning. In P. Brézillon & A. J. Gonzalez (Eds.), Context in Computing (pp. 255-269). New York: SpringerGeitgey A. (2016). Machine Learning is Fun! Part 4: Modern Face Recognition with Deep Learning.

King, D.T., Winner, E. & Ginns, I. (2011). Outcomes and implications of one teacher's approach to context-based science in the middle years. *Teaching Science*, 57(2): 26-30.

Pentland, A. (2005). Socially aware computation and communication. *Computer 38*(3), 33-40.

Picard, R.W. (1997). *Affective Computing*. MIT Press, Cambridge, UK,

Psyché, V., Anjou, C., Fenani, W., Bourdeau, J., Forissier, T., & Nkambou, R. (2018). Ontology-Based Context Modelling for Designing a Context-Aware Calculator

Roschelle, J., & Teasley, S.D. (1995). The Construction of Shared Knowledge in Collaborative Problem Solving. In C. O'Malley (Ed.) *Computer Supported Collaborative Learning*, (pp. 69-100). Berlin: Springer-Verlag.

Sandoval, W. A., & Bell, P. (2004). Design-Based Research Methods for Studying Learning in Context: Introduction. Educational Psychologist, 39(4), 199-201. doi:10.1207/s15326985ep3904_1

Schwartz, R.S., Lederman, N.G.& Crawford, B.A. (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, 610–645.

Schwarz, B. B., & Baker, M. J. (2017). *Dialogue, argumentation and education: History, theory and practice*. Cambridge University Press.

Tardif, J. (1999). *Le transfert des apprentissages*. Montréal : Les Éditions Logiques.

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

Wang, F., Hannafin, M.J. (2005). Design-based research and technology-enhanced learning environments. *Educational technology research and development*, 53(4), 5-23.

Zimmermann, A., Lorenz, A., & Oppermann, R. (2007). An Operational Definition of Context. *Lecture Notes in Artificial Intelligence*. 4635, 558-571