Web-Based Context-Aware Science Learning

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ABSTRACT
In this paper, we describe an innovative project where Web technologies are exploited to foster science learning in an integrated but mobile smart learning environment. Context-awareness is considered a crucial skill in science learning, and we therefore imagined a solution to train students for context awareness by illustrating context gaps based on on-site observations and measurements. A component named MazCalc contains the parameters of each context and allows us to compute the context gap and its potential to stimulate context-awareness among students. International collaborative learning is structured in such a way to induce students to make comparisons and discuss the topic studied. Experiments are being conducted in Biology and are in preparation in Geology.

Keywords
Context awareness; science learning; web-based learning.

1. INTRODUCTION
This paper contains 8 sections. The first section introduces the problem of context-awareness in science learning. In the second section, we expose our hypothesis and methodology to foster context-awareness among students. The third section contains the instructional design that we imagined in order to implement and test our hypothesis, as well as the design of the context gap calculator. In the fourth section, the web services and their integration in a platform are described. In the fifth section, we summarize two experiments that were conducted in Biology. The sixth section introduces ongoing and future work, and is followed by a conclusion.

2. THE PROBLEM OF CONTEXT AWARENESS IN SCIENCE LEARNING
Context constitutes an inherent part of scientific studies and should be an inherent part of science learning. Despite this universally recognized fact, students at all levels are trained to study science out of context. Etymologically, the term *context*, comes from contextere (lat.), to weave together. Ontologically, a context is a set of things that are structurally or functionally linked together around a thing in the center, such as the context of a word, of an action or event, etc. For Abowd et al. [1], "a system is context-aware if it "uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task".

Science education studies such as those involved in a context-based approach [2] [3] are interested in natural and ecological contexts, or in the observation of students during learning activities, particularly in the context of field investigations [4]. Our study is in this paradigm but focuses on using the comparison of two particular contexts in building students' knowledge and observation skills.

3. HYPOTHESIS AND METHODOLOGY
Fostering context awareness among learners can be carried out in different ways: 1) direct instruction on what context is, why it is important in science, how to become aware of and to handle context issues or context-dependent phenomena; 2) discovery learning where learners have to discover the existence of the context, the role of context, and how to tackle context issues; 3) example-based strategies, which guide the learners to understand the concept of context through examples. We imagined an innovative strategy, by which learners are put in a situation where they face contrastive differences of the same phenomenon which can be explained only by the role of context. This strategy can qualify as a kind of "guided discovery". Our hypothesis is that this strategy is effective for developing context-awareness among learners. In order to test this hypothesis, we designed a structure for an instructional scenario that has the potential to produce what we call a "context effect", which is a collision between the observation data collected in two natural contexts, resulting in a challenge for interpreting them, and leading to a conceptual change. Our approach is to measure the context-effect potential by calculating the context gap between two contexts. This technique allows us to predict the probability of a context effect, and to calibrate the instructional scenario accordingly. The instructional design hypothesis relies upon several principles: 1) orchestration of individual, team and group work within a goal oriented structure provides a general framework while leave room for emergence; 2) collaborative learning is effective both for cognitive and metacognitive tasks, and for sustaining motivation; 2) videoconferencing allows for 'live' events (such as surprise,

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spontaneous questioning) that are not possible through text communication; 3) teamwork is appropriate for investigation, data collection and analysis; 4) sharing data induces questioning and discussions, which develop scientific reasoning, 5) teacher role is to organize and guide the inquiry and the discussions, and to make sure that appropriate conceptual change is happening.

When considering several methodologies, we found that the Design-Based Research (DBR) methodology is appropriate when the goal of the research is to refine or test a hypothesis through the design of an innovation, and through *in situ* experiments [5, 6]. Each iteration can vary in terms of specific objectives and research techniques. The output of one iteration becomes the input for the next. DBR emerged in the late 1990's as a new paradigm for testing both human interventions and technology-enhanced learning environments. Sandoval and Bell [6] adopted DBR for science learning with various adaptations. The methodology is microsystemic and based on iterations that allow both to refine the hypothesis and to adjust the innovation jointly with the actors in place. In our case, the first innovation is the context gap instructional scenario, and the second one is a web-based system including the context gap calculator.

4. INSTRUCTIONAL DESIGN AND CONTEXT GAP CALCULATOR

Instructional scenarios provide a structure of activities for all actors involved [7]. They are goal-oriented, and limited in time and space. We designed such a structure where two groups of learners in different contexts study the same object or phenomenon, and share their results. In this structure, each group (20-30 participants) is divided into teams (3-6 teams per group) that work on the same topic. During the activities, the students conduct investigations, make observations, collect data, share and discuss their results both inside the team and between groups. The scenario is led by the teachers who also collaborate and together moderate the discussions [8]. The key issue for the effectiveness of this scenario is the existence of a context gap, and we consequently imagined a way to calculate this gap using parameters that characterize the phenomenon in both contexts, but have a different value in each one. Our calculator, called MazCalc, uses parameters related to the discipline (biology, geology), and allows us to enter the values for each context. For the frog experiment, all data collected related to the scale of the organism (compared to the scale of the cell). But in geology, we had to introduce the use of scales to allow the comparison of parameters between contexts. We are currently elaborating the equations that will calculate the gap based on the values of the parameters for each scale.

5. EXPERIMENTS IN BIOLOGY

Learning science in context often means fieldwork, with observations and data collection. Our first experiment (2013-2014) involved one group of children in Quebec (Canada), and one in Guadeloupe (French West Indies), all 11 or 12 years old. The theme was the frog, and the topics were: frog call, morphology and taxonomy, environment, relationship with humans, and developmental nutrition.

In the case of the Caribbean frog, named *Euleutherodactylus johnstonei*, it is the smallest existing frog, lives in houses and gardens, and produces a strident song. The Quebec frog, named *Lithobates catesbeianus*, is the largest in North America, its tadpoles survive in icy waters, and its song sounds like a bull's cry.

Learners used tablets and mobile phones to collect data and record their activities, and a web platform to share and discuss their observations, including during field observations (Figure 1).

Figure 1. Learners at Fieldwork in Guadeloupe

Vanier data collection and measurement tools were used for field work, as well as videoconferencing to share direct observations with remote team members.

Figure 1 shows a team trying to find tadpoles in a pond close to their school, before they discovered that they were mislead by their misconceptions, In Guadeloupe, common frogs live in houses and dry gardens, and the tadpoles that they found were from toads.

Interviews with learners were carried out before and after the experiment to assess their understanding and representations of the topics. They were asked to imitate the call of the frog, and to draw a frog. In most cases on both sides, they would produce the call of and draw the 'standard' frog that they know from stories, comics or movies. After the experiment, most answers were changed to adjust to their observations and discussions.

First results indicated a powerful context-awareness effect among learners on both sides, as well as an effective conceptual change. Modifications suggested were to encourage inter-individual exchange among learners, informal and unrecorded, as it happened spontaneous among teachers. The main challenge was the synchronization of the efforts on both sides, despite the fact that the time zone is the same, as is the language (French). Technical problems were the main source of synchronization issues, and we expect that they will be solved for the following iterations.

A second experiment in biology started in the fall of 2014, with the same teachers and their new groups, and with 'water' as the theme of study. The topics studied are: water cycle, organisms living in water, fishing, source of energy, the water inside living organisms, salt water, freshwater, dangers, and sea transportation. These topics were selected jointly by the teachers and learners of both groups. Fieldwork included going to the river (or sea) shore, making observations and measurements, and collecting samples. On the Quebec side, we used videoconferencing to have the teacher from Guadeloupe interact lively with the group while they were doing the fieldwork. We also added an expert in Water science who asks and answers difficult questions.

6. INTEGRATED WEB SERVICES

The roles of computer technologies in science learning are manifold, from mobile learning to smart learning environments, simulations, serious games, online laboratories, and fast evolving technological innovations. Cloud-based environments allow to integrate a variety of tools that can import, export and exchange data, which can then be visualized and shared for interpretation and discussion. A specific role for computer technologies in our innovation is to model the context in order to predict context effects and their potential for productive learning. In this project, we adopted the perspective proposed by Tawfik et al. [9] for mobile and cloud-based environments for science labs [10] and we follow the work in progress by the IEEE-SA P1876 ™ Working Group Meeting on Standard on Networked Smart Learning Objects for Online Laboratories (http://standards.ieee.org/email/2012_09_cfp_P1876wg_web.html). According to Salzmann and Gillet [10], a smart device has sensors and captors, possesses self-awareness, and the capacity to reason and learn. They are autonomous and collaborative. While Salzmann and Gillet envision smart devices to serve online labs and enrich the MOOC paradigm to become Massive Open Online Labs (MOOLs), our intention is to develop hardware intelligence in the forms of small mobile networks that interconnect these devices with their users and with remote team members, in quasi real time.

This project shares several aspects with recent or current research projects: Go—Lab (http://www.go-lab-project.eu/frontpage), Science Created by You [7], WISE [11] and the project *Researching Better Ways to Teach 21st Century Science* (Zimmerman, https://www.hampshire.edu/faculty/timothy-zimmerman). With the Go-lab project, we share the use of software tools and online labs framed inside an inquiry learning circle. Similar to SCY, we emphasize the role of scenarios for orchestrating collaborative learning. With SCY and WISE, we share the view of learning by inquiry, collaboratively and with software tools, but these projects do not consider learning outside the classroom. We consider science learning via observation of the natural context (fieldwork) to be an essential component in natural sciences, as is developing skills to learn with Science 2.0 tools. For these reasons, we are ready to tackle technical issues such as how to have (quasi) real-time importation of data during fieldwork together with videoconferencing with remote team members. Our project is in line with the general view developed by [12] in their book entitled 'Seamless Learning in the Age of Mobile Connectivity'. However, the framework for Web services according to this view is still to come.

As a first stage of technological integration, the instructional scenario has been implemented in a Learning Management System (LMS, Moodle), in order to interconnect the activities with the resources needed, and to facilitate the recording and the tracing of the data (Figure 2). The initial scenario can be modified along the experiment to make room for emergent activities or requests from learners.

It is our intention to run three iterations in biology on different topics but with a similar scenario structure, before producing final results. Two experiments in geology are in preparation, one on Magma and one on Geothermy. While running the experiments, we make progress in the design and the development of our web based system, in two directions: the integration of a mobile science lab, and design of a context-aware tutoring system.

Figure 2. The Moodle interface for teams working on the frog

7. ONGOING AND FUTURE WORK

The architecture of a context-aware intelligent tutoring system (CAITS) with its authoring services is proposed as illustrated in Figure 3. One key issue in developing successful learning environments or tutoring systems is to provide the system with a valid learning scenario. In this authoring system, the Maz-Calculator (MazCalc) is a key service, used not only for estimating the context effect frequency but also for highlighting the context parameters that are involved. The author can then use this information to revise the learning scenario. She can be assisted in this adaptation task using CEM tools combined with three scenario management tools (CAS-Edit, CAS-Viz and CAS-Sim) as described in Figure 3. In this way, it will be possible to iteratively play with the context parameters provided by MazCalc and adjust the scenario accordingly. The resulting scenario is stored in the CSLS database.

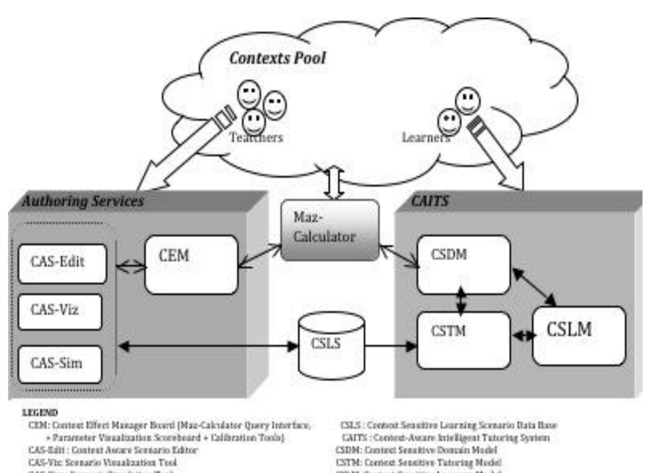

Figure 3. Conceptual Architecture of the CAITS

As shown in Figure 3, the Intelligent Tutoring System itself (CAITS) comprises three main components. It is connected to the context pool in three ways. The first connection is implemented by the interaction between the MazCalc and the CSDM; this connection makes it possible to provide the ITS with context effect information which will drive the domain model behaviour. The second connection is a direct link to the context pool which gives access to other contextual parameters to be considered during interactions between the learners and the system; this includes contextual information about the learners' profiles, as well as instructional/learning strategies. The third connection is done through the CSLC database allowing the CAITS to load relevant instructional scenarios that will drive the tutor behaviour.

Our planning for the near future contains several components: 1) Completing the design and development of MazCalc, including testing with two themes in geology, 2) Completing the second iteration in the biology experiment (2014-1015) 3) Analysis of the results for the second iteration followed by corrections, 4) Third iteration in the biology experiment (2015-1016), 5) Final results for the series of experiments, 6) Integration of the mobile science lab, 7) Development and implementation of the CAITS.

8. CONCLUSION

A work in progress project in science learning based on context effects has been described, which uses the web as a distributed platform for online and mobile science labs, and for tutoring services based on the calculation of context parameters. First results indicate that our hypothesis is a productive one in producing the context awareness and the conceptual change among learners in biology. Difficulties encountered are related to synchronous communication between the two groups.

The levers for success have been identified as the following: 1) the instructional scenario contains a good balance of discovery and guidance, of intra- versus inter teams work, and of planning versus emergence, 2) international collaborative learning is highly motivating both for teachers and for kids, 3) commitment of teachers in this enterprise, 4) support of parents for allowing the outing and sometimes even accompanying them,

Final results for biology will be produced after three iterations, in 2016, and the experiments in geology are planned to start in the fall of 2015.

Further work consists in carrying out the iterative design experiments, testing and implementing the MazCalc, integration of the mobile science lab, and moving towards the implementation of a web-based CAITS.

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