Adaptive learning scenarios for detection of misconceptions about electricity and remediation

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***Abstract*— Our main objective is to model the knowledge used by learners in order to solve problems about electricity. We are searching means to do a diagnosis about student's activity based on a microworld of electric circuits. Once the diagnosis realized, we try to provide the learner with the most relevant remediation with regard to his/her misconceptions.**

***Index Terms*—Adaptive educational scenario, Computer based learning environment, Diagnosis, Electricity, Remediation.**

I. INTRODUCTION

Each learner has got initial conceptions for explain electric phenomenon, before his coming into the physics' classroom. These conceptions condition the physics learning and they can be correct, but sometimes theses are not. In this case, these misconceptions can be a problem for the learning development. We can observe in electricity, but in other subjects too, a resistance of misconceptions [1]. Although, it is necessary to consider theses misconceptions in order to transform them into more elaborated conceptions, better adapted for the learning situations and providing an improvement potential.

For this, a pedagogical scenario allows to destabilize the learner's misconceptions and incorrect reasoning. In addition, the scenario helps the learners to progress and establish new knowledge [2].

Our works has a triple aims: the first one is to establish a diagnosis of the learner's conceptions in the domain of electricity. This diagnosis is based on actions and argumentations given by the learners. The second one is to destabilize the learner's misconceptions and the last one is to remedy, as good as possible, to these misconceptions.

For this, we have collaborated with physical science teachers of school and secondary school. Together, we have designed a didactical and pedagogical scenario for *detection*, *destabilisation* and *remediation* of misconceptions about electricity.

II. RESEARCH CONTEXT: THE « SHARED VIRTUAL LABORATORY » PROJECT

The goal of the « Shared Virtual Laboratory » (SVL) project of the Kaleidoscope1 Network of Excellence is to provide resources and tools to enhance research in the domain of Technology Enhanced Learning (TEL). Our team is involved in this project; we have built an experimentation platform to help a researcher to carry out a real experimentation on TEL [3]. A set of tools were developed and integrated to an existing platform to show how the process of an experiment setting up can be automated.

The experiments done for our research project on electricity learning, presented in this paper, were done in May 2005. They were very useful to design and validate this experimentation platform. To describe the students' activity during an experiment (the learning scenario), the SVL experimentation platform provides the LDL language [4] [5]. This language allows the researcher to describe the activity of all the participants of an experiment (learners, teachers, researchers, etc.), collaborative aspects can be easily described.

The platform provides a LDL interpreter. The scenario interpretation consists into defining the participants and their roles, and selecting the services and contents required by the scenario.

The execution of the scenario will provide the required resources (learning objects, services, tools, documents, etc.) to each user involved in the activity.

In June 2006, we carried out another set of experiments on electricity learning. The adaptive learning scenario was more dynamic and described with the LDL language. The experimentation traces were automatically collected into an XML database provided by the platform. The scenario modification and correction were easier for the researcher than with the previous scenario described with JavaScript and Php/Mysql.

III. THEORETICAL FRAMEWORK OF OUR RESEARCH

A. *Misconceptions and incorrect reasoning in electricity*

A misconception is a conception having a domain of validity [6]. A misconception can be considered as an error or as a pertinent knowledge in a specific context. For example, in algebra, the expression $(a+b)^2 = a^2 + b^2$ is a misconception : it is correct when a or b is null.

In the electricity domain, many misconceptions have been described [7]. The problem is that the students change hardly theirs misconceptions, in spite of the teaching of electricity. Some studies show that several misconceptions, sometimes conflicting [8], can be observed for the same learner. The misconceptions, detected with our scenario, are the following:

- **"Wear" of the current:** With this misconception, the students think that the current is lower at the

[1] http://www.noe-kaleidoscope.org

output of an electrical dipole than at the output, because the electric dipole consumes a part of the current. This conception is false, in accordance with the first law of Kirchhoff, the intensity is everywhere the same in a series circuit.

- **Confusion about the role of switches:** Some students think that in a complete circuit, the current does not flow and vice versa. They inverse the role of switches. For some authors [9], the origin of this confusion can be a sequential reasoning.

- **Sequential reasoning:** For the students applying a sequential reasoning, the circuit is not considered as a global system. The students read the circuit sequentially in the conventional current direction [10].

- **Conventional current direction inversion:** Learners inverse, sometimes, the conventional current direction.

B. *Studies about resistance of misconceptions*

Research studies show that the electric circuits are rarely mastered when students leave the secondary school [11]. Another study shows that we have similar results between school students and university students [12].

Moreover, a study of the conceptions about electric, realized in five European countries and concerning 1200 students (14-15 years old), shows that the students have the same difficulties. The system scholar and the language should not influent this result [13].

IV. ADAPTIVE LEARNING SCENARIO

We have designed and developed a dynamic questionnaire, in order to destabilize and remedy misconceptions, by confrontation of the learner's prediction to simulation results. This scenario is centred on an activity where learners will use a microworld of electric circuits, called TPElec[2], in order to verify his/her hypothesis. The use of a microworld can have a positive impact on the destabilisation of misconceptions [14]. However, the free use of the microworld does not guarantee the learning. That is why; it is necessary to give some goals to the learner thanks to a relevant educational scenario [15], [16].

A. *Didactic hypothesis*

- **Simulation by using a microworld:** Our scenario is based on the using of a microworld. For our scenario, the microworld is used as a confrontation's strategy in order to facilitate the conceptual change for the learner [17] [18] [19]. The didactic hypothesis is that the microworld can be the support of relevant scientific and educational activity. It allows the articulation of didactic model with interaction's model between the learner and the instrument [20].

- **The role of argumentation:** The process of argumentation can be potentially constructive of new knowledge [21]. It allows improving learner's behaviours about knowledge used, to explicit the reasons of a given solution (explanations, justifications, arguments) and to elaborate more coherent explanations [22].By asking the learner to justify his answer, we want to better know the learner's reasoning and conceptions. The learner answer is based on his/her initial conceptions. This choice is justified by the fact that "it is necessary that the environment allows the learner to express and communicate his mental model" [23]. The argumentation is an important factor in the misconceptions detection. Thanks to the argumentation, we can detect the situation where the learner gives a correct answer with on incorrect reasoning, and the opposite situation.

[2] http://siota.imag.fr/TPElec

B. *Problem's linking*

- **Adaptive question in accordance with the learner's answer:** We have designed and developed a set of problems, as a dynamic questionnaire. The corresponding questions are presented according to the learner's answer. The next illustration shows an extract of the different ways the learner can take in accordance with his/her answer.

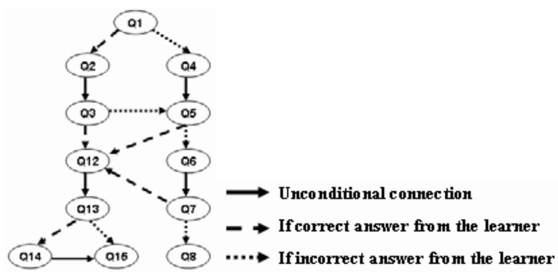

Figure 1. Extract of possible ways according to the learner's answer

- **Didactic variables:** In our scenario, we wanted to handle didactic variables, because they help to create adaptation and regulation for the learner [24].
  - ***Didactic variable: definition***

A set of problems can be defined from a learning situation, by modifying the value of variables, changing the characteristics of the strategies of solution (complexity, validity…). Only the modifications changing the hierarchy of strategies are taking into account (relevant variables). Among the relevant variables, the ones that a teacher can handle are particularly interesting: these are the didactic variables [24].

  - ***The using of didactics variables in our scenario***

In our scenario, the question's linking is realised by the handling of didactics variables. But, we handle also these variables inside a question in order to diagnose incorrect reasoning in the learner's explanations.

For example, in a question we modify the order of the electric components (the electric circuit is given by the figure 2). This change has an impact on the reasoning of some learners who think that the intensity is lower at the output of an electric resistance. These learners think that the lamp of left's circuit is lightening less that the lamp of right's circuit, because an electric resistance is before. In this question, we can see if the learner has understood or not the first law of Kirchhoff about electricity in a series circuit. In this case, the learner applies a sequential reasoning.

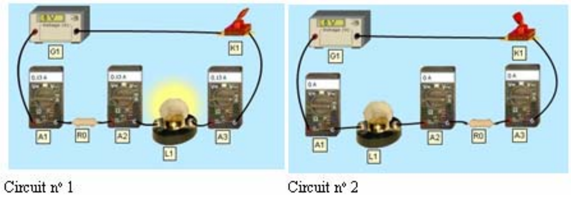

Figure 2. An example of didactic variable

C. Description of the learner's activity

The activity, realised by learner, is based on a confrontation of their prevision about an electric phenomenon and the results obtained from the microworld. This activity divided into three kinds of questions:

- **Position question:** the learner takes a stand on an electric phenomenon, for this s/he chooses an answer from several possibilities and s/he gives an argumentation.
- **Remediation question:** according to the learner's answer and the diagnosis realized, we propose him some questions for remedy about his misconceptions or incorrect reasoning.
- **Progression question:** if we observe that the learner answers correctly, we propose more difficult questions.

D. Confrontation prevision VS microworld

In these questions, we want to destabilise and remedy electric misconceptions by the confrontation of the learner's prevision about an electric phenomenon and the results coming from the microworld. For this, the questions are articulated in two steps:

- in a first step, the learner makes a prevision about an electric phenomenon
- in a second step, the learner builds the corresponding simulation with the microworld and s/he compares his/her observation to his/her previsions. Then, s/he has to write a conclusion.

The figure 3 shows an illustration of this confrontation.

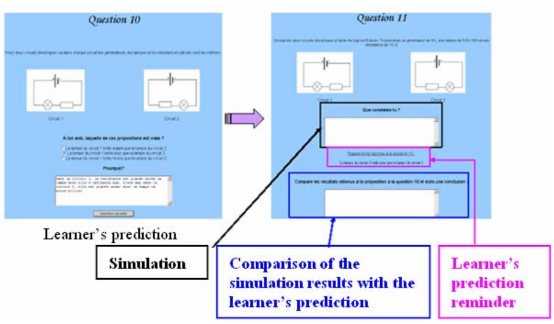

Figure 4. An example of a dynamic question sequence

V. Experiments

A. Population

Our scenario was experimented with 92 secondary school learners aged from 13 to 16; these students were divided into four groups:

- two groups from the 3rd year of secondary school: one before electricity teaching, and one after teaching
- one group from the 4th year of secondary school after electricity teaching
- one group from the 5th year of secondary school (no electricity teaching during this school year)

B. Analyse before experiment (Hypothesis)

We wanted, with these experiments, observe the resistance of misconceptions. We think that the misconceptions tend to reduce with the teaching, but we think that they reappear for the students who are in the 5th year of school because they do not have electricity teaching.

Another of our waiting was to know if we were able to detect and destabilise the students' misconceptions. For this, we observed the evolution of the learners' answers (thanks to the collected data).

We wanted to observe if the students' argumentations can establish a more pertinent diagnosis and if the simulation helps for the destabilisation and the remediation of misconceptions.

C. Misconceptions and incorrect reasoning detection (Results)

Thanks to experiments, we have detected the following misconceptions and incorrect reasoning: current wear, confusion about the switch's role, confusion current direction inversion and sequential reasoning. The next figure shows these detections.

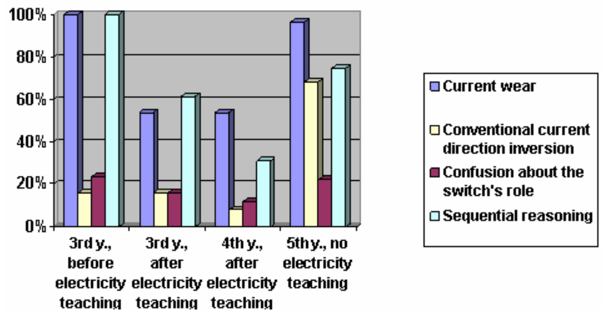

Figure 3. Detection of misconceptions and incorrect reasoning

In accordance with the figure 4, we notice that the current wear and the sequential reasoning are strongly detected, and this whatever level and progress of school program (before and after teaching).

D. Analyse and interpretation after experiment in regard with argumentation, simulation and scenario

- **Role and benefits of the argumentation:** In regard with the answers given by the students, we obtained two categories of answers particularly interesting: correct answers based on an incorrect justification and incorrect answers based on a correct justification. An example is given in figure 5. These categories show that the argumentation is important to detect a misconception and/or an incorrect reasoning. It also helps to detect reasoning errors for a learner giving a correct answer.

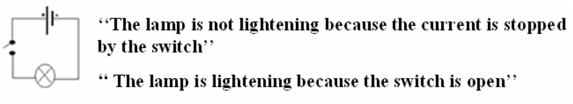

Figure 5. An example of correct answer based on incorrect arguments and the inverse case

- **Benefits of the simulation:** We noticed that the simulations destabilise learners' misconceptions. The analyse of the trails shows that 67% of students were destabilised by our confrontation prevision/microworld strategy. For 75% of these students, a remediation was operated.
- **Role of the scenario and the didactic variables:** When we modify the order of an electric dipole in an electric circuit, some misconceptions appear. In figure 6 (left), we permuted the place of a switch and a lamp. We asked to the students if the lamp is lightening. In the right of figure 6, we give the percentage of correct answers. We can see less correct answers for the circuit 2, for each circuit and for each students group. For this circuit, the students think that the lamp is lightening, justify their answer with following argument: "the switch is after the lamp". In this case, we can establish a sequential reasoning.

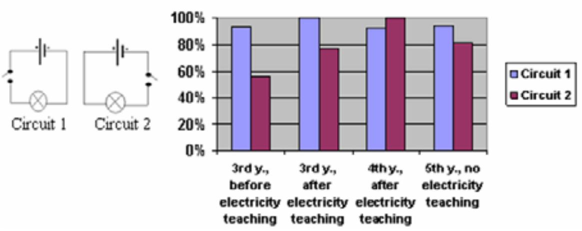

Figure 6. Percentage of the correct answers for each circuit and each students group

- **Impact of the remediation:** The analyse of the path and the answers of all the students, we detected 118 cases where the students change their opinion, we have classified these cases in 3 categories:

- no relevant : the answer and the argumentation given by the student are the same as the first time.
- relevant and correct : the student changed his/her incorrect answer and incorrect argumentation into a correct answer with a correct argumentation.
- relevant and incorrect : the student changed his/her correct answer and correct argumentation into an incorrect answer with an incorrect argumentation.

If we consider relevant case only (correct and incorrect), we can see that for 77% of these cases, the changing is positive: the student changes his/her opinion into a good one.

VI. Conclusions

With the results of our experiments, we can say that our adaptive learning scenario helps to destabilise misconceptions and incorrect reasoning of students in the electricity domain. Our analyse shows that the simulation helps for destabilisation and remediation. The conflict between the learner's prevision and the results given by the microworld, encourages the students to change their incorrect reasoning.

Moreover, the analyse shows that the argumentation given by the students favour a better detection, a better diagnosis (and a better remediation).

Our goal is to integrate, to our microworld, a formulation's environment and a diagnosis more elaborated agent. This diagnosis agent will give the needed information to the teacher in order to help him for understanding the students' activity. The formulation's environment will allow the students to express hypothesis or observations about electric phenomenon. This formulation will improve the diagnosis. To realize this, we are working on language acts, to simplify the learner's answer analyse.

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