To set up pedagogical experiments in a virtual lab: methodology and first results

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Abstract:

This paper concerns a methodology for setting up web based experiments by distinguishing two perspectives: the learning perspective (which tasks will be scheduled for pupils and tutors, how they are planned and what learning objectives they may attempt), and separately, the experiment perspective (how teachers or researchers may use trails of this experiment, the first to improve their teaching, the last to various research objectives). The both are described by computable "scenarios" expressed with an educational modeling language, Learning Design Language (LDL). Scenarios are then implemented on a platform (LearningLab platform) to be played by pupils and tutors and further analyzed by exploiting trails of each run.

1 Introduction

A great part of our research within MeTAH team aims to develop e-learning models, tools and environments for teachers. Among our results, we find the microworld of electric circuits called TPElec, and works in the field of Educational Modeling Languages. For several years, we have established a fruitful collaboration with members of another French research Team that led to the Learning Design Language specification (LDL) [1]. We recently proved that the use of TPElec in combination with a formal description of what users (pupils and teachers) have to do, and how they may interact during a planned session, can foster the use of TEL in education [2].

1.1 Context of our work: The "Mates" project (Methodology and Tools for Experimentation Scenario)

Initiated by the Kaleidoscope NoE (http://www.noe-kaleidoscope.org/pub/), the MATES initiative extends our previous work and aims at providing a platform and a methodology for setting up pedagogical experiments, by designing scenarios, implementing them on a platform and collecting effective trails. This methodology includes some ways to analyze effective trails of each experiments compared to the planned trails [3]. In the MATES project, we envisaged to illustrate our proposals with a new experimentation in the field of electricity. This experimentation, named "LearnElec" is scripted in conformity with the LDL language. We have not only a good ground of experimentation with classes of physics and their teachers, but we take also the following observations as basis: Teaching in experimental sciences traditionally involves the learner in practical work or lab work sessions. These sessions are often collaborative sessions, where pupils are invited to assess and consolidate their knowledge by working in small groups. One observes great generics in the organization of these sessions: introduction, formation of small groups, distribution of materials, experiments, synthesis and finally, final assessment of the session. One significant advantage of using web based learning to set up such sessions is to reduce costs and logistic difficulties inherent to the necessity of using real materials and disposing of specialized classes. Another one is that, collaboration can be differently and more efficiently established.

1.2 Several reasons that led us to use an EML

It seems obvious that we could have designed and developed a web-based application according to a very different approach. Nevertheless, like a great deal of researchers in computing science for education, we are convinced that the use of an EML - like IMS LD [4] – for designing computable models of the educational situations we want to set up, is a gage of flexibility and reusability. Secondly, while such languages aim to provide precise information about roles, tasks, time scheduling, results to be obtained, we claim that LDL includes particularly attractive concepts that allow us to describe *a priori* which observations will be specially made during a session. In addition, whereas the IMS LD authors claim that this EML is not focused on a particular pedagogy, LDL is collaboration-oriented, that means that its core concept is *interaction* [5]. Interactions are situated (in *arenas*), they may be governed by rules (e.g. when or why a special interaction may occur) expressed on *positions* taken by the inter-actors (e.g. help demand, score obtained, click on a submit button, etc.).The following point has to be especially considered: LDL offers means to express which particular value taken by an element or a combination of elements will be significant during runtime. Thus, it naturally leads us to distinguish into separate “scenarios”, the pedagogical and the experimental. The first scenario corresponds to the teaching wishes of the teachers with whom we worked. The latter, concerns the manner of managing the observation of the learning situation during runtime and may be widely different according to the actors for whom it is intended (researchers who want analyze trails, teachers who want increase efficiency of their pedagogy, etc.). The combination of these two scenarios that we describe below constitutes the basis of our design methodology.

2 The pedagogical scenario

2.1 Description

2.1.1 Objectives

Research studies show that the electric circuits are rarely mastered when students leave the secondary school [6]. 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 [7].
In the MATES initiative, teachers want to make work their students about the concept of the “power of a lamp”. So, they confront them with an unusual situation where in a simple series circuit two lamps, “visually similar”, don’t glow with the same brightness (Figure 1). Outside of the personal expertise of the students’ results and questions, the choice of this situation is justified by the fact that even if it concerns the power of a lamp, some students think that electricity wears out when crossing a lamp. Another reason of the student’s “misconception”

lays on their sequential reasoning[1]. Thanks to the Kirchoff law, we do not doubt that if the two lamps are really similar, they get equally bright when we turn on the switch … In fact (and we experimented this), a good deal of students first claim that it is absolutely normal that the lamp close to the battery shines more than the other one!

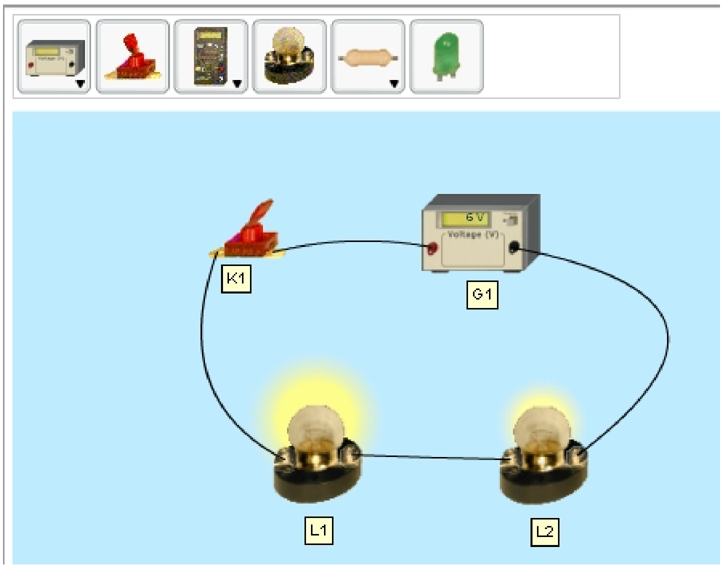

Figure 1: a strange situation where one lamp shines brighter than the other…

2.1.2 General strategy

The classroom is organised in groups where pupils have to: answer MCQ questions, debate in order to produce a common synthesis of their answers, manipulate individually TPElec and negotiate together to arrive at the best manner of testing their hypothesis.
A very large part is given to collaboration through debates [8] and collective writing of conclusions. To foster collaboration, pupils receive nicknames as soon as they join the session. On another hand, we take care of different problems that may merge when grouping pupils together: for example, deliberate confrontation of pupils of different natures would prevent the most timid from giving opinions [9] and thus the collaboration would fail. So, we decided of a dynamic grouping strategy that is set up after a first MCQ step: as far as possible, pupils who gave different answers are mixed in a same group. Tutoring too is deeply considered (following debates, intervening if necessary in group’s chat). Each tutor will be responsible of less than three groups thus he will be more helpful for pupils and may be able to limit renunciations linked to the feeling of isolation of pupils [10] or locate quickly an isolated one [11].

2.1.3 The different phases of the pedagogical scenario

Six phases numbered from 0 to 5 constitute the pedagogical scenario. In each phase, two main roles are distinguished: tutor (physics teacher) and student. Each phase alternates individual work periods and collective ones. Phases 0 (launching), 4 (assessment of the group) and 5 (assessment of the class) are detailed below separately. The three other are built on the same “pattern” that could be illustrated by the figure 2.

[1] For the students applying a sequential reasoning, the circuit is not considered as a global system. They read the circuit sequentially in the conventional current direction

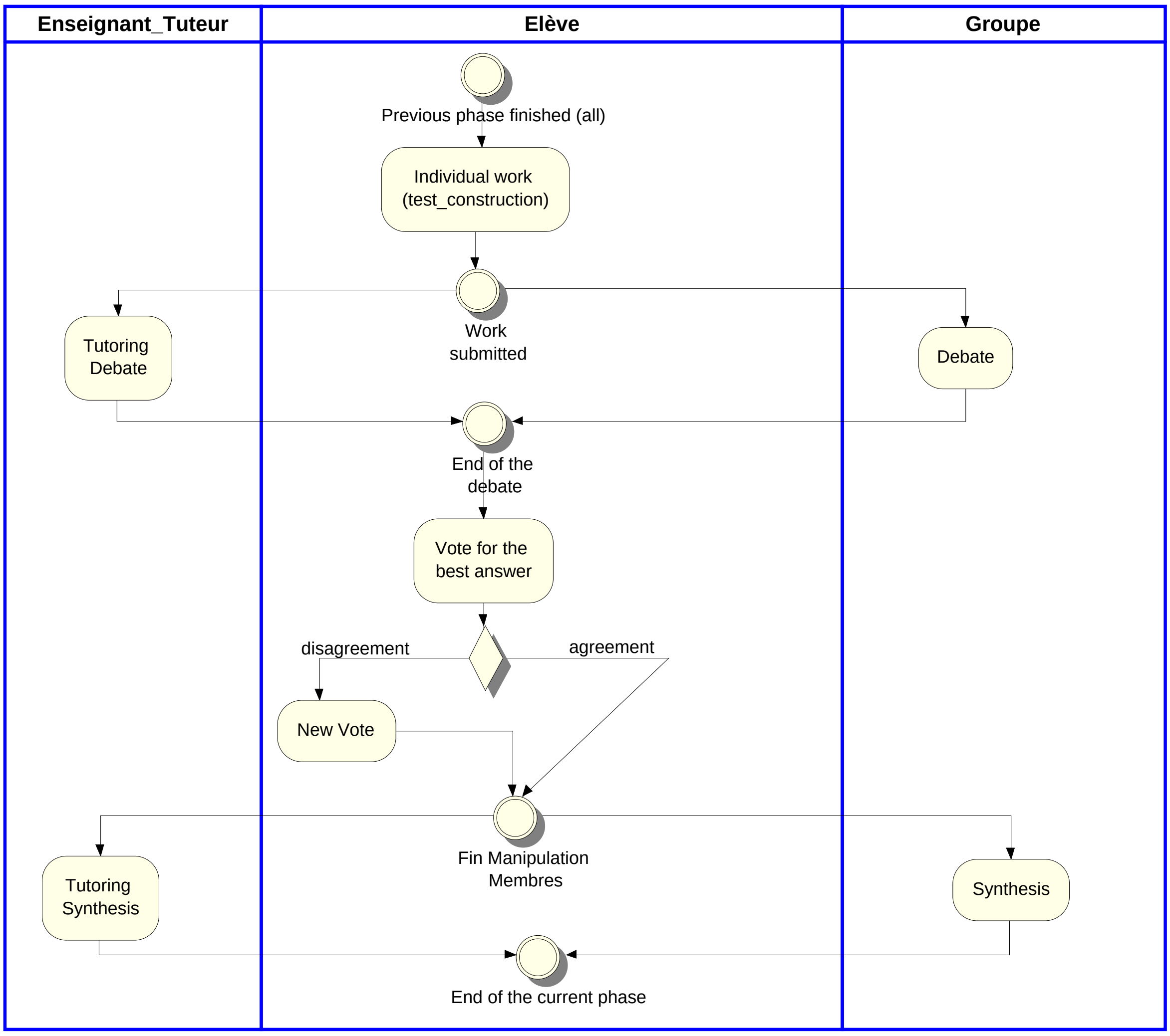

Figure 2: Graphical representation of the pattern used for phases 1, 2 & 3

As we discussed in previous works [12], teaching takes into account, more or less consciously, a great variety of diagrams or patterns, that are not to be considered as a mechanization of the teaching activity, neither as simplistic: whatever their nature, these schemas express teachers' expertise, pedagogical strategy or organizational constraints, that are in turn interesting to capture when designing "e-learning situations". In fact, a really generic pattern of the phases 1 to 3 has been used to design with only slight adaptations, essentially about resources to be employed (documents, tools, services), timing or sequencing of the different steps. At this time of the MATES initiative, we only spotted it with graphical representations (using conceptual maps or some others) and, waiting for the finalization of a really user-friendly editor for LDL, by "copy and paste" of the main XML lines which translate this pattern.

Phase 0 of the scenario determines the dividing of the class into small groups: A first MCQ is proposed concerning the phenomena illustrated in figure 1. As related in the next section, groups are automatically formed by mixing together students of different answers to this first question and tutors are simultaneously allocated to one to three of these groups. Phases 4 and 5 are assessment steps, the former given by each tutor to the groups to whom he is responsible and the latter to the whole classroom. During the whole activity, tutors are aware of the students' work: a chat allows each of them to follow exchanges between the members of their groups, help them and foster their collaboration and considerations if needed. Thanks to chat, the students are going to argue of their choice and this exchange can be potentially constructive of new knowledge [13] 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 [14]. Notice that no automatic feedback is given (e.g. by the way of an ITS), tutors intervening according to their wishes (as in a real classroom).

2.2 Designing with LDL

2.2.1 Main concepts

The following picture shows a simplified view of the LDL meta-model.

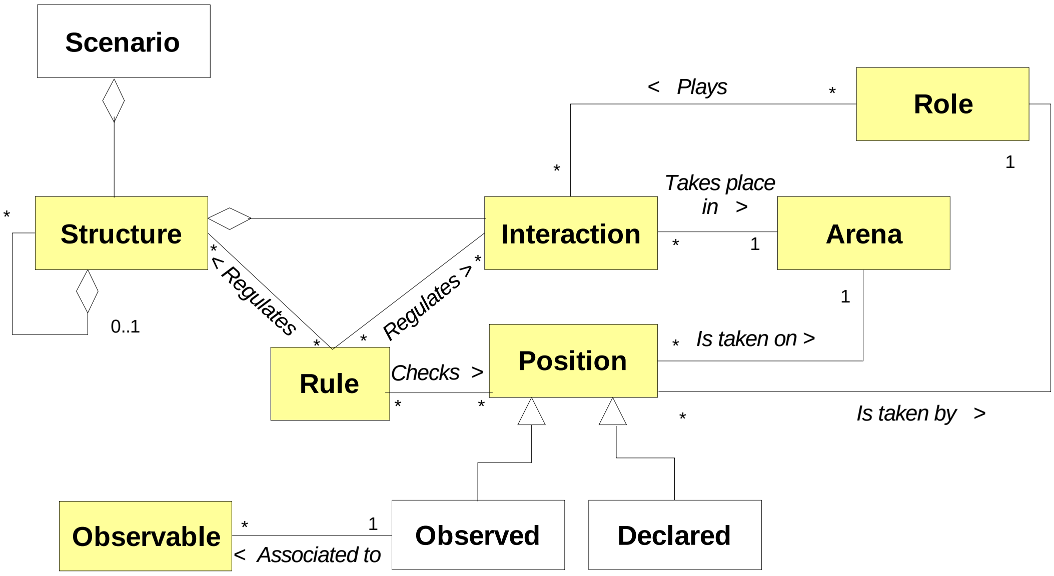

Figure 3: A simplified view of the LDL meta-model

The main concepts to describe any learning scenario (even if it is not a collaborative one) are:

- **Structure**: a set of interactions organized sequentially, in parallel, or without any order. One can see a *structure* as the learning flow.
- **Interaction**: the core concept of LDL. *Interactions* specify the exchanges the participants will have together during the activity.
- **Arena**: all interactions are situated into one *arena*. An arena may be any learning object if taken in its broad sense as encompassing multi-media documents, tools and services.
- **Role**: a *role* is defined by the list of the interactions in which participants who hold it are involved.
- **Position**: a *position* is taken by a role within an interaction. It may express various things like a “click” on a particular button, a numeric result to an exercise, a help demand, a teacher’s remark, etc.
- **Rule**: *rules* are useful to control the learning flow (e.g. start/stop one interaction) or regulate the activity (e.g. launching a special interaction when a particular position is taken by a role).
- **Observable**: an *observable* is a sensor used to evaluate “observed” positions. Observables are very powerful elements that allow producing structured traces of activities.

2.2.2 How dynamics is taken into account in the pedagogical scenario

In the launching phase (phase 0) students have to answer to the first MCQ where the choices A & C are considered as correct but where choice B (“Current across L1 is higher than across

L2") corresponds to a misconception. The choice of one answer by a student is traduced by a *position* in LDL. This position is linked to an observable thus it becomes possible to launch a script (algorithm) whose function is double: forming groups and distribute them to the tutors. This reveals the interest of the couple position/observable: we have just written in LDL a rule triggered when every students have answered the MCQ (answer = position). Because there are linked to an observable, all the previous positions are stored in an Exist database and then read by the script launched when the rule is evaluated so that groups can be formed dynamically.
In the LearnElec pedagogical scenario, dynamics don't end with the groups' formation. In fact, thanks to the use of positions, observables and rules referred to them, each time a member of a group answers a MCQ or builds a circuit with the TPElec microworld, its results are picked up to be dynamically displayed to the whole group he belongs to. That amounts here to build dynamically arenas where debates take place (figure 4).

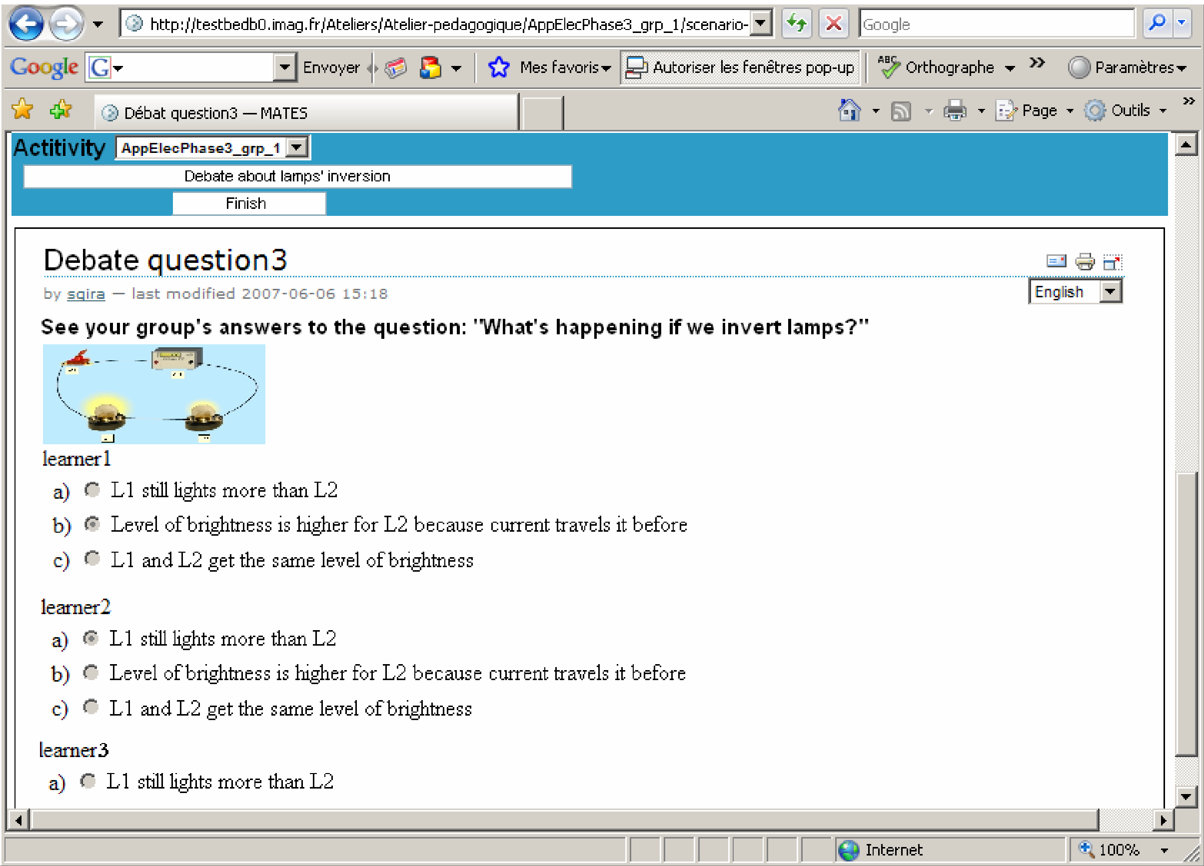

Figure 4: The debate arena (phase 3)

2.2.3 Managing collaborative work with LDL

In the LearnElec scenario, the students have alternatively to work alone (with the MCQs and TPElec) and to collaborate in small group, for debating on their hypothesis or for writing synthesis together. An important pedagogical choice is to decide the way each collaborative session must end.
LDL allows different possibilities through the conditions, For example, the session ends when an actor takes the position of ending, or when all the actors have taken this position. In addition, we can define a time limit condition that can be combined with the users choices. So, the different phases of the parallel work in several groups can be finely described in the script of the scenario, using the concept of position.

2.2.4 Tutors' awareness

Teachers, with whom we worked, wanted students to collaborate together instead of guiding them. Therefore the main task designed for tutors consists in allowing them to intervene into the chatting times or when, thanks to a shared text editor, the group they are in charge to write a synthesis of the current learning step. Their own interactions always flow in parallel with the students' ones. Nevertheless to keep tutors aware of their groups' work, the significant *positions* taken by students when interacting are set up with a special property: *shared position*. So tutors may follow the student's progression and if needed advice the experimenter (see section 3) that something is going wrong.

3 The experiment's scenario

In order to facilitate the setting up of one experiment, the preparation and the launching are described in a scenario of experiment. This particular scenario is in turn traduced in LDL.
The roles involved in an experiment's scenario are the *experimenter* and all the other participants of the learning situation. This scenario consists of three phases: the *preparation*, the *learning phase* itself and the *exploitation* of results. The preparation phase has to be managed by the experimenter, who chooses the pedagogical scenario and allocates one or more roles to each other participant (e.g. teachers, learners ...). After that, the learning phase can be launched. At this moment, the pedagogical scenario is instantiated on the platform and the actors can play their roles according to the model of the pedagogical scenario. As soon as one is logged, he is informed of his group's number and of which activity he has to run. At the same time, the experimenter can observe and exploit the effected trails produced by the different actors involved in the pedagogical scenario.
In the following paragraphs, we point out different consequences in such a way to formally distinguish between what come under organizational matters and what concerns learning or observation of it.

3.1 Preparing several instances of the same pedagogical scenario

A great advantage to have scripted the scenario with an EML is the possibility to instantiate easily the same scenario (model) in various contexts. The experimenter has mainly two tasks to instantiate a pedagogical scenario: (1) preparing the list of the expected actors and allocating one or more roles to them (here: tutor or learner); (2) linking physical tools, services or learning objects for each arena. What is important is to notice that these tasks are managed by the *preparation phase* of the experiment's scenario that is clearly separated of the pedagogical one. So, it becomes possible for an experimenter (e.g. a teacher), to prepare in advance different sessions of the same experiment that would be deployed later with different classes.

3.2 Adapting resources according to the participants

When linking physical resources with the arenas, the experimenter can contextualize them according to particular parameters as the size of the class, student's age, or, more prosaically, the speed of the computers that will be used (in this previous case, the experimenter would avoid to link heavy objects with some arenas (e.g. "XXL" pictures) when more light ones could be used instead without damaging the pedagogy. More significant contextualization may occur: in the Mates project, it was decided that groups were dynamically formed according to the answers given by the learners to the first question. The grouping modalities are defined thanks to an algorithm what is launched when everyone has submitted its answer.

Widely, different grouping strategies may be used and only depending of which algorithm is linked to the corresponding arena described in the pedagogical scenario.
Other examples could illustrate these contextualization facilities.

3.3 Observing the student's progress

The experiment's scenario gives means to the experimenter for observing the progress of any participants enrolled on the pedagogical scenario. If something gets wrong, he can intervene during the session and try to solve the problematic observed situation. For example, if the experimenter notices that one or more students work very slowly and make their mates wait too much so that they can't go ahead, he may decide to allocate these students to another "tutoring activity" (e.g. reading deeper explanations about the power of a lamp), or, more strongly, to force them to attempt the next step of the current scenario.
Taking into account a researcher's point of view, the observation's facilities allow pedagogues or didactic researchers to better understand reasoning of learners in order to provide them later with the most relevant remediation.
Every interaction occurring during a session produces contextualized trails that are collected into one *Exist* Database. Thus the later can be analyzed at any moment during or after sessions.

4 Conclusion

In this paper we have shown a way to script a rich and complex collective learning situation. The setting up of the experiment and the collecting of trails have been facilitated by the LearningLab platform, developed in the framework of the MATES project. The proposed methodology is based on the concept of scenario, both at the pedagogical level and at the experiment level. That is remarkable to notice that the pedagogical scenario and the experiment scenario have been both described in using the LDL language. So, the same language LDL is used at different levels of abstraction, this ability showing its expressiveness and its power.
We can hope that using our methodology on a platform like LearningLab and describing scenarios in a modelling language like LDL, will allow more easily researchers and teachers to carry out collective learning experiments.
At this current time of the Mates Project, we have set up three different experiments with French students and physical teachers (secondary school). We have planned new experiments with English students for the very next months thus French and English trails collected will be compared, formed with specialized tools and analyzed by researchers, member of the Noe Kaleidoscope network.

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