Classroom Simulator, a new instrument for teacher training. The case of mathematical teaching

Hussein Sabra[1], Fabien Emprin[1], Pierre-Yves Connan[1], Christine Jourdain[1]

Abstract

In this paper we present the design method of a Classroom Simulator that can be used in teacher training. The construction of the Classroom Simulator is focussed by the action of the teacher and learning progress of the pupils. The design of the Classroom simulator is based on the principles that ensure that it reacts close to reality. The collection of experiences can also help to identify rules, invariants in the relationship between the action of the teacher and the activity of the pupils. The classroom simulator is designed as a "part scale simulator" with a professional problem to be solved by the trainee.

We present a mathematical situation especially around solving problems using ICT. This situation has been widely experimented in real classrooms. The experiments of this situation have allowed us to analyse and understand the professional knowledge of mathematics teachers mobilized to make choices.

Keywords. Classroom Simulator, didactical teacher choices, dynamic geometry, ICT, instrumental genesis, problem solving, teacher training.

1. Introduction

We present in this paper the Classroom Simulator (CS) designed in a research project at the University of Reims-Champagne Ardenne. This tool is currently in the form of a prototype.

In a previous research [1] on training practices, the researchers in mathematics education proposed the use of a video of a teaching session to introduce a component of *reflexivity* in the sense of Schön [2]. The videos of teaching practices establish a *professional problem* that trainee teachers must resolve. But, in this form of training session, the video as resource for the training, have a limited potentials (limited viewing time; the trainee cannot interact on the situation observed and with pupils). That is why we have been led to develop a CS that allows teachers to experiment their solutions during the training session. It was designed following a *contructionnist approach*: for Papert [3], the computer is a great tool to test theoretical knowledge, then by the CS we can find a practical solution to a professional problem and not only a theoretical one.

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[1] University of Reims Champagne Ardenne URCA, CEREP (Research Centre on Employement and Professionnalisation), ESPE (postgraduate school of professorship and education) de l'académie de Reims, France

The main idea of our CS is to implement simulated classroom session wherewith we aim to put the trainee teacher in the professional situation where he/she has to make choices. All choices are then recovered by the user, in pdf file form, for fostering the *reflexivity* on his/her own practice. The main aim of this paper is to analyse the design process of the CS that by the presentation of a classroom simulated session. This design process is part of a projet financed by the D. R. R. T. (regional directorate of research and technoloy) of Champagne Ardenne. The simulated session focuses on mathematical teaching; in particular the problem solving using ICT (dynamic geometry).

We start in this paper with the presentation of the conceptual framework which could allow us to locate the CS in the landscape of professional training simulators (§ 2.1). Then, we present on the one hand, the two-fold approach (§ 2.2) following which we conducted didactical choices to build the part scale simulator and on the other hand, the instrumental approach (§ 2.3), which allows us to study the design process of the CS (constraints and potentials) based on the instrument we want trainees to build. Then, we move to the presentation, depending on the conceptual framework, of the CS design process (§ 3). This process contains the main bases on which the CS was developed (§ 3.1); the mathematical situation implemented in the CS (problem solving using ICT) (§ 3.2), we highlight particularly the phase of conjecture (§ 3.3). We end with a conclusion and perspectives.

2. Conceptual framework

2.1 The simulators in the professional training

The Simulators exist in many professional training such as aircraft pilots, engineers on nuclear power plants. Pastré [4] identifies several types of simulators:

- the *full scale simulators* which aim to reproduce as faithfully as possible the reality. The function associated to this type of simulator is the training ;
- the *part scale simulators* that focus on a specific part of the subject's activity. The function associated to this type of simulators is to resolve a specific professional problem.

In the field of teacher training, Morge [5]-[6] designs a simulator regarding physics education. The simulator he built is based on a word processing software with references across pages. It focuses on the simulation of language interactions during the class session.

We choose as Morge to build a part scale simulator that suits our training process based on the confrontation of a problem but we make different assumptions about software programming:

Our previous research on training practices [7] has shown us the importance of taking into account several dimensions of professional practices. We choose to simulate the pedagogical and didactical actions of the teacher and their effect on student activity and behavior.

Our work on simulators in other fields [8] leads us to believe that the appearance of software matters. The current prototype should take advantage of current IT tools with the incorporation of moving or still images of student productions, sounds and why not educational software.

2.2 Teaching knowledge and ICT

In this work we are faced with two types of practices: teaching practices and training practices. We therefore chose to use theoretical frameworks that can be used both to analyse teaching and training practices. The twofold approach defined by Robert [9] looks at professional practice as a recomposition of five components described in the following quote: *"Our analyses start from class session in which we distinguish components, institutional, social, personal, mediative (related to the unfolding in the classroom and improvisations), cognitive (related to the prepared contents and expected unfolding), closely dependent for a given teacher, and having to be recomposed: it is necessary for us to think of the components together, and to estimate the compensation, balance, the compromises to include/understand and start to explain what is concerned"* [10, our translation].

This approach is called two-fold because it combines two theoretical frameworks :

- a didactical framework, specific to the situation of education in a given discipline (mathematics in our case) ;
- a cognitive ergonomic framework that allows analyzing the individual work.

It is therefore possible to implement this framework in the training situation by transposing elements related to teaching in training. The simulation is a reduction of reality, two-fold approach allows us to control the reduction of dimensions of teaching practices. We will focus more on the mediative and cognitive components.

2.3 The instrumental approach

In our research study, the training session considered, focus on the mathematics teaching using ICT. Therefore, we need to combine the two-fold approach with a framework for understanding the learning situations using ICT. We chose to use the *instrumental approach* of Rabardel [11]for which the instrument is built by its users, from an artefact. We have therefore to analyse the *instrumental genesis* through a double process of:

- *instrumentalization*, assigning function to the artefact by the subject ;
- *instrumentation*, feedback whereby the artefact causes the subject to adapt to its constraints.

The instrumental approach is relevant framework to analyse the simulated classroom session focuses on the problem solving using ICT. But in this paper, we use this approach to analyse the construction of different instruments by the teacher trainees from our CS:

The instrumental genesis is a complex process, linked to characteristics of the artefact (its potentialities and constraints) and to the subject's activity, her/his knowledge and work methods. In our case, the artefact is the CS and the subject is the teacher trainee.

3. The process design of the Classroom Simulator

3.1 The basic principles

The design method of the simulator has been the object of a process taking into account several parameters:

- the teacher actions (didactical and pedagogical actions). The teacher actions take place in the real classroom. In the CS the teacher actions are simulated and take the form of the *choices* that the trainee execute when he/she uses the CS;
- the learning progress. The learning progress is complex to quantify. We simulate it in the form of pupil states that appear in the form of inscriptions on their PC screens;

- the simulation of classroom session time;
- the interactions between teacher and pupils. Each action of teacher has an effect on the learning progress of the pupils. In the CS, these interactions take the form of trainee choices and their effect on the pupils state.

The teacher practices are necessarily singular and unrepeatable. Asking a teacher to animate the same scenario in two different classrooms, we observe that the teacher choices are not the same; because the pupils' actions are not the same. Even if we request from two different teachers to animate the same situation in the same classroom, the classrooms situations are hardly comparable. The simulation of the classroom session is a process which evolves according to the duplication of the experience and the validity of the results is empirical. We develop the simulator in the line of *constructionist approach*, very similar to that advocated by Papert [12] with regard to how we learn to handle the software.

Several studies highlight the difficulty of mathematics teachers to animate in the classroom sessions using ICT. Several reasons are on the source of this difficulty. For example:

- the appropriation of the technology by the teacher. As a user, the teacher during training can develop an instrument for own mathematical activity. However, the teacher in the classroom will assist the instrumental genesis of the pupils;
- the appropriation of ICT by students needs time and the classroom session could quickly deflect the didactical object of teacher to a technical questions related to ICT.

Taking into account these difficulties, we intend by the CS to develop teaching knowledge related to the ICT. For this object, we assume that the development of a simulator part scale is associated to professional problems. The professional problems take into account the dimension of the reality and could facilitate the construction of specific teaching knowledge related to the ICT.

We simulate a classroom session (in our case a mathematical classroom session) that allows the teacher trainee to perform a set of choices and he/she immediately tests it in the simulator. He/she then has a feedback that allows him/her to consider other set of choices then test it and so on. By using this simulator, the teacher trainee makes a hypothesis and confronts it to the "simulated reality". He/she can then make several tests on the CS.

We chose to manage the timing not in a realistic way but by assigning a cost (in minutes) to each choice. In this simulator, the time is also simulated. The real time is therefore not included in the CS. The teacher trainee takes the time he/she wants to make his/her choice and every choice made has a "time cost". This choice is purely didactical: choosing a progress in real time encourages *reflection in action* as in reality; while choosing a simulated time allows *reflection on action* within the meaning of [4]. This corresponds more to our didactical issues to favor the construction of ICT teaching knowledge developing reflexivity throughout choices. Thus the teacher trainees can think all they want before making a choice and the simulation of a one hour classroom session can be done in a few minutes.

In our CS it is impossible to go back and modify a choice that has been done before. Making possible the flashbacks decreases the weight of equities and makes it difficult for teachers to control errors testing approach. In this design choice, we approach the real behavior of a teacher who tries to adjust the choices made previously by making new choices and not by cancelling it. We want trainees to be in a reflection on the action, this requires that choices have consequences. We also choose to make trainees' activity indirectly accessible through its production and its answers.

If we offered the choices based on the teachers' actions and pupils states observed and then simulated, we take the risk to guide trainees towards actions which they would not necessarily have thought. We chose to leave out some hidden options, but may be released at the request of trainee. Based on data collected around the real sessions observed, we chose to simulate the actions that influence pupils‘ learning, and also pedagogical actions that enrich the simulated session. The trainee will have information on the mathematical activity of students, but also on the level of attention. The attention is programmed to give indirect information, but fast on the effect of the trainee choices.

On pupil screens, the trainee can see the pupils states or the answer to a question he chose to ask He/she can also go to a particular student and so zoom in on a pupil PC. In addition, we added an indicator of attention or concentration of the student who is driven by rules related to the understanding of the task. The choices are of two types, individual or collective. The trainee may choose to apply to all pupils or only one. Talking to each pupil consumes more time than speaking to all pupils, in which case the information provided may not be heard by all.

To summarize, we have simulated a part of mediative and cognitive components of practices by limiting types of mediations and choices.

Instrumental approach allows us to analyse how the teacher trainee constructs his/her own instrument (For example, the number of attempts shown when trainees test different hypotheses). The nature of some attempts that could be described as suicides (students seek to make the class unmanageable as soon as possible or test aberrant choice) is a marker of instrumentation and research of the software limits. The fact that working on simulator brings experience to students is also an indicator of instrumentalization as this teacher trainee explain:

“[I have learn, by using the CS] *how already arranging a teaching session at the beginning* [...] *I do not know, explain instructions with the monitor on or not, impacts, indeed, I had never really thought why before today“*

3.2 The situation of mathematical teaching simulated

The mathematical situation chosen is the problem solving using dynamic geometry (table 1). The situation is what we call in French “an open problem” referring to [13]. This type of problem is called “open” insofar as no specific solution is expected: what matters is pupils’ search.

Programming the simulated session is structured around four critical phases in the problem solving using ICT:

- phase of communication to the wording: there is only pedagogical action simulated there. Trainees can not choose what they say to pupils but only the way they give instructions: are screens turned on or turned off for example;
- phase of the construction: pupils have to draw, in a dynamic geometry software (like cabri ®, geoplan,…) a circle with two perpendicular diagonals. Two points (B and F) on the circle and their orthogonal projections on the axes (A and C, E and G);
- phase of conjecture: pupils have to answer the question : “What is the longer of the two segments, [AC] ou [EG]?” by using tools available like moving point to specific position or measurement tool. A correct drawing, that is to say a drawing that resists to moves. To resist drawings have to be made with software’s function as “perpendicular at a point … on the line …”. If the action is ignored, measurement on the software will be different;
- phase of proof: this last phase strongly depends on the other. A correct conjecture help to find basics of the demonstration: OABC and OGFE are rectangles, so we can

deduce that [OB] and [AC] length are equal and that [EG] and [OF] are also equal. B and F are on the same circle which center is O so [OB] and [OF] are equal. By transitivity [EG] and [AC] have same lengh. In this phase an important point is the pooling and what is written on the blackboard and on pupils' notebook.

<u>First wording :</u> Make the figure shown in the opposite. (you begin by the circle, two perpendicular diameters, then you put the points B and F. Afterwards, you will continue the construction in accordance with the coding). What is the longest of the two segments, [AC] ou [EG]? **<u>Second wording:</u>** Make the figure shown in the opposite, following the next program : Draw a circle and put it center O. Draw two perpendicular diameters. Put a point B on the circle (as in figure). Draw [BC] perpendicular to [OE] and [OF] perpendicular to [OG]. What is the longer of the two segments, [AC] or [EG]?

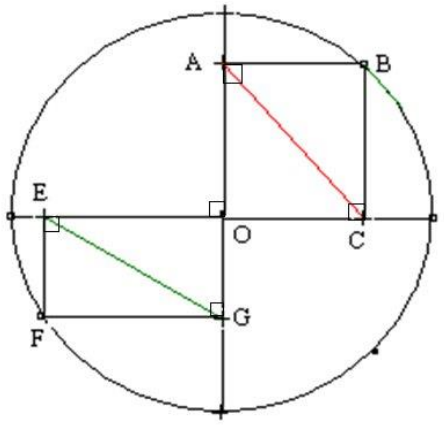

Table 1. *The problem solving in the session simulated*

We filmed the implementation of the situation repeatedly. We collect data on pupils' activity in terms of the teacher actions of the teacher. We study and analyse all potential teacher/pupils interactions in each of four phases of the problem solving using ICT. Then, we construct a conceptual diagram structured around the four phases described above (extract of diagram in figure 1). This diagram models the teacher actions in terms of choices, which the trainee could be execute. We extracted from the complete diagram the choices that determine the transition in the simulated session, from a phase to another.

The choice to move from one phase to another is determined by the trainee (by the choices: go to construction, go to the conjecture, go to the proof). However, this choice has consequences on the didactical progress of the session and the mathematical progress of pupils. Changing phase it is change in the nature of mathematical activity, which change therefore the nature of the teacher actions. This aspect is present in our simulated classroom session, we illustrate this point in the following section.

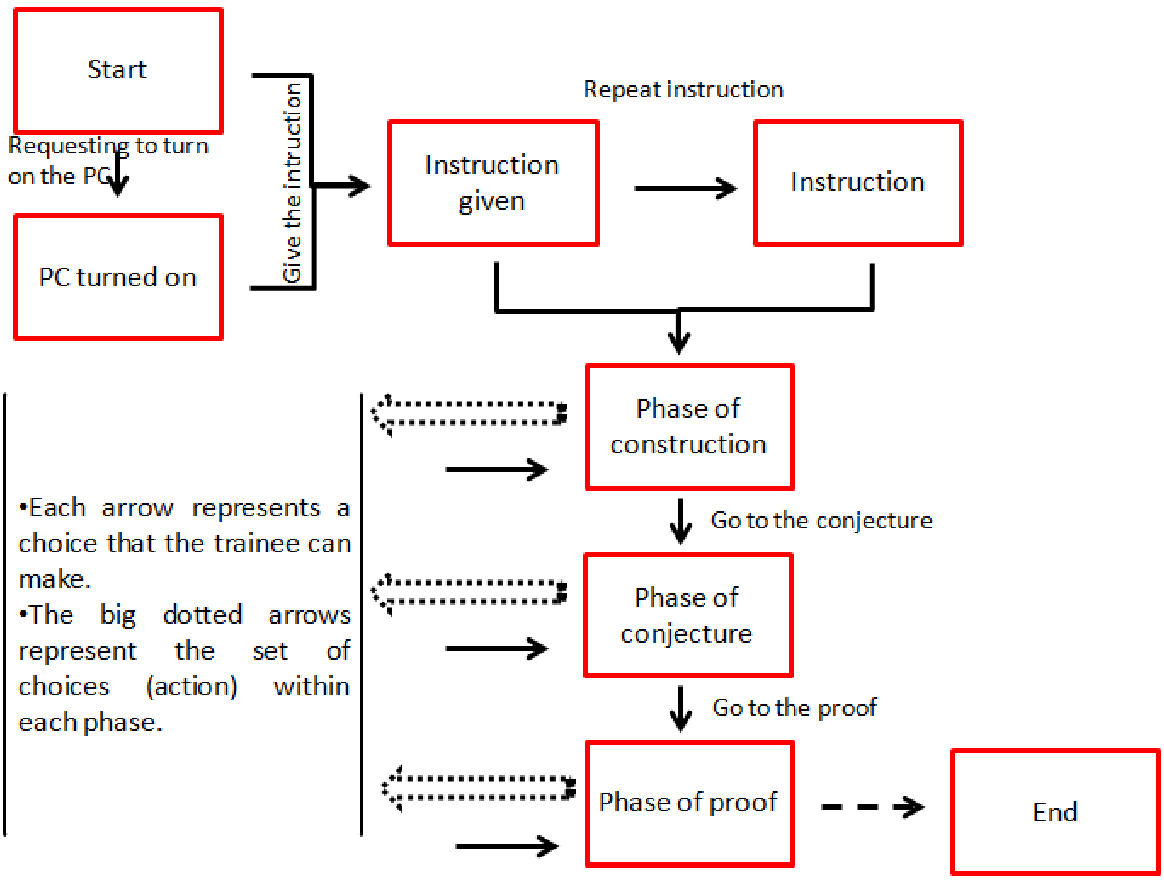

Figure 1. *The extract of conceptual diagram that represents the choices based on the potential interaction teacher/pupils and structurend around the four phases.*

3.3 The simulation of trainee choices and pupil states, phase of conjecture

Different types of interactions are possible inside each phase. The simulation of these interactions is based on three main elements (§2.1):

- pupils' states like the fact that they have understood the instruction or not, the fact that they managed to draw something resisting;
- teachers actions simulated by choices, like asking pupils to turn the screens on, asking pupils to move points of their drawing to know if it is well constructed;
- the influence of trainee choices on pupils' states.

The return to the previous phase isn't possible. The trainee should choose the right time of the transition to the next phase. Deciding to move to next phase could have effects on the mathematical progress of pupils (could foster the heterogeneity). Within a phase, the choices are reversible (see figure 2). We note that in "collective conjecture help", there is the choice "help to finish the drawing figure", although we are in the phase of conjecture (see figure 2). It is an available choice that the trainee execute for tending to synchronize the pupils' activity. However, this is a choice which is costly in simulated time. Therefore, the choice to move to the next phase should be closely linked to the kind of pupils' states in the problem solving.

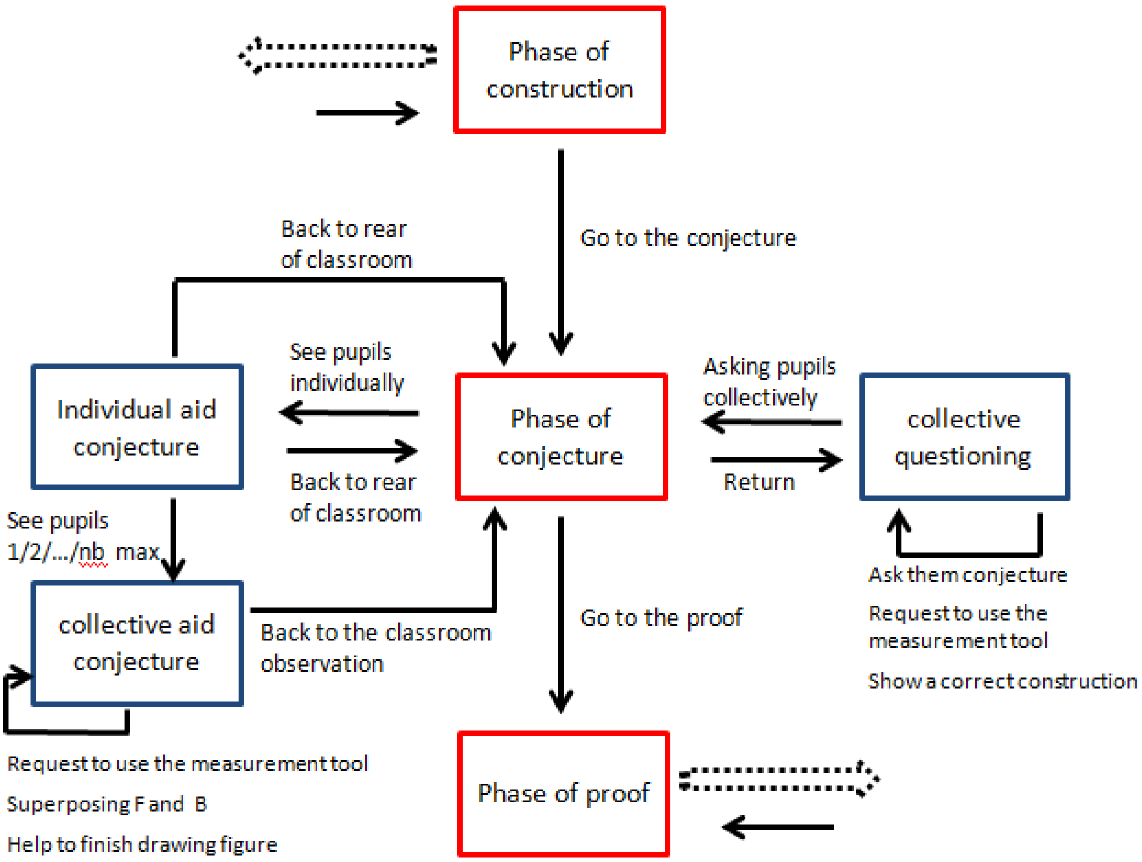

Figure 2. *The set of choices within the phase of conjecture*

To create a scenario in SC, we have to enter on a database all the pupils' states, the teacher choices and to link them. The links depend on the pupils' activity. For example on our script, we have the state that could appear on the pupils' screen "conjecture is correct". To reach this state, the previous one must be "drawing is resisting". If not, there must have an action of teacher that gives pupils a correct drawing (individual or collective conjecture help, figure 2). Experience in real classroom is important to set the effects. For example, if ten pupils are in the state "drawing is resisting" without any teacher action there is six pupils that reach the state "correct conjecture" and four that reach the state "I don't know" but none that reach the state "false conjecture". The proportion of each response is determined by our analysis of the situation actually implemented. If the teacher asks the pupils to use measurement tool these four pupils move from the state "I don't know" to the state "correct conjecture". In this way, the real experiments of the situation in classrooms are useful for calculating the proportions of students regarding to the actions.

The simulated actions of the teacher are of two types: individual or collective. The trainee may work with all the students or only one pair. The second option is more time consuming if you want to go in all pairs, but the first one takes the risk that not all pupils have access to the information given. So the teacher trainee has to make the most appropriate choice in a given time of the session progress.

All the parameters described in this section lead us to build the CS with an interface into two components (Figure 3):

- the view on the classroom and pupils' screens;
- the control panel that shows the session time and the choice available to the teacher trainee. In figure 3 we see the four choices presented in figure 2;

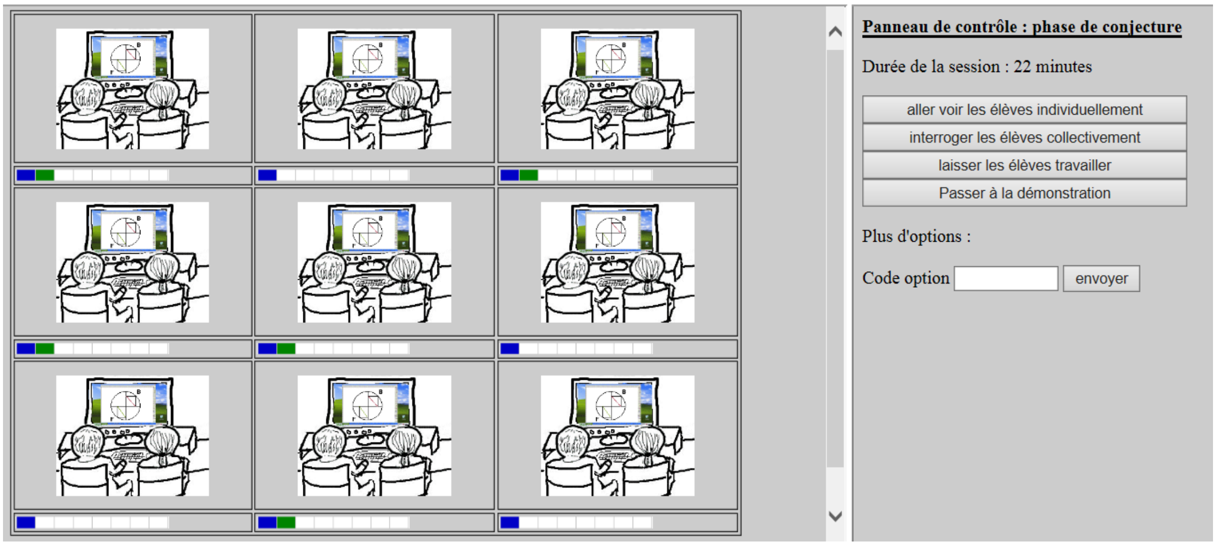

Figure 3. *The old interface of Classroom Simulator. To the left, the four choices of the phase of conjecture; to the right the pupils states (a new interface is under construction)*

4. Conclusions and perspectives

We designed a simulator around four phases structuring the problem solving using ICT. This structure will be tested by considering several levels of teaching (middle school and high-school), even more mathematical fields (geometry, algebra, etc.) and other school subjects. Papert [3] believes that the most important in learning is to provide the learner the tools to build their knowledge. In this context, he noted that the computer appears as an ideal tool for exploring the world and apppropriation knowledge. The devolopment of CS inscribed in the Papert approach.

The method of implementation of the simulated classroom sessions, encourages us to continue our work with new teaching situations. The collection of experiences can also help identifying rules, invariants in the relationship between the activity of the teacher and the student reactions and learning progress.

Our aim is also to add to a CS a questionnaire part to gather information about professional practices of users. The main variable will be the teacher (his profile, age, seniority, gender, training, etc.). We propose to implement an innovative and original methodology, based on the collection on a large scale (several hundred teachers) actions of teachers through the CS. To achieve this goal we need to make the simulator available online while controlling access. It offers a fully controlled situation and reproducible activity. The use of the simulator will take place primarily in the context of teacher training. For this purpose, we develop training scenarios taking into account the co-construction of two instrumental genesis:

- the trainer, who will build an instrument for developing professional knowledge of teacher trainees about the use of ICT in mathematics classrooms;
- the trainee, who will build an instrument to solve a professional problem related to the use of ICT in mathematics classroom;

The problems related to instrumental genesis of the pupils is not taken into detail in this version of simulator. By the way, this is the major difficulty that teachers encounter when he/she is using ICT in teaching session. This constitutes a perspective to this research design development.

A second perspective of this work is that the simulation of the transition from the phase of the conjecture to the phase of the proof. This transition is so complex. Some studies in the geometry education report this complexity [14]. We need a detailed analysis of this transition before trying to simulate it.

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