

Description of the experimentations in Switzerland & Italy

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8.1 Introduction

For some years now, researchers in the field of education have been seeking to improve and design pedagogical activities in which learners are invited to enter into enquiry and argumentation processes. This dialogical context is conceived as a rich arena for knowledge co-construction.

However, using argumentation as a learning tool in the context of schools raises questions and difficulties at different levels, institutional as well as psycho-sociological: argumentation is rarely an object of study nor a familiar discursive tool in classrooms, because teachers sometimes think that organizing argumentative debates is time consuming and do not feel comfortable with this kind of social organization. Designing argumentative activity is indeed a difficult matter. From the participants' side, argumentative communication may be perceived as a situation where their relationships with their schoolmates are at risk because it involves confrontation and expression of conflicts.

In the frame of the ESCALATE project, we felt the importance of both exploring the psychosocial issues of argumentation in learning, in particular mediated by TIC, and of working with teachers or future teachers on designing TIC mediated argumentative scenarios in the sciences. In order to sustain and facilitate argumentation and learning processes, we used the software called Digalo (developed in the frame of the DUNES project⁴). already used in previous studies (Muller Mirza, Tartas, Perret-Clermont & de Pietro, 2007). Some experiments used other ICT tools, among which Microworlds, elaborated in the frame of the ESCALATE project.

This document is the account of four experiments in several educational contexts in Switzerland and in Italy. We collaborated with the Department of educational sciences research unit of the University of Salerno in order to have an opportunity to reflect upon the possibilities of disseminating scenarios that had been developed in Switzerland. We will report here on observations of researchers and teachers' efforts to design and implement effective argumentative activities, paying particular attention to the context in which each case has been tested. From these we gather interesting cues on the difficulties and potentialities of such designs. One of the most important conclusion in our eyes is that, as much as the pupils probably learned in arguing, in this process collaborative process involving researchers, University students, teachers, teacher trainers, school authorities, and pupils, researchers certainly learned as much, if not more, to better understand the psychosocial and cultural conditions of argumentation.

Argumentation is a purposeful activity, requiring specific social and cognitive skills. It is a demanding dialogical process that is more likely to occur if the matter of the task can be discussed in a "secured" space in which identities are not threatened and efforts can go into decentrations and critical evaluations of multiple perspectives. The latter are not only "view-points" but also information that are semiotically organized and function as mediations in the picturing of reality and its on-going co-construction in the course of conversation.

⁴ DUNES (Dialogical argUmentative Negotiation Educational Software) is a European project coordinated by Baruch Schwarz, Hebrew University of Jerusalem, and funded by the Vth Program Frame of the European Commission (IST-2001-34153). It involves 9 participants, academic partners and software developers, from France, Germany, Greece, Israel, the Netherlands, Sweden, Switzerland and the UK.

8.2 Cases A & B: the Storm and Digalised Euglena

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In this text, we shall present implementations of two scenarios (or cases): the first one is called the “Storm case⁶” and the second one the “Digalised Euglena⁷” case. Both have been developed and tested in several classrooms in Switzerland. In our account, we will develop the specificities of the institutional and social context and describe quite precisely our preparatory work, the strategies and methods we have chosen, the main results we reached, as well as the teachers and the learners’ opinions about the whole process. From the analyses of the data gathered, we will try to shed light on the “lessons learned” from an educational point of view.

We therefore will ask in particular, and give some elements of response about:

- how and in which context the cases have been elaborated;
- how and in which context they have been implemented;
- how the experiments have been perceived by the teachers, what they think about the use of Digalo and the contributions of the activity in terms of learning ;
- how the experiments have been perceived by the participants, what they think about the use of Digalo, and the gains in terms of learning and argumentation that we can infer from the data.

Our contribution focuses on the description of two case implementations that we did in various contexts, “Digalised Euglena” and “the Storm”:

- The **Storm case** was tested in two different environments:
 - with 9-10- year-old pupils in one classroom in Geneva (in the text, we will refer to this experiment by means of the following acronym “Storm1prim” – as it is the first version of this case and we tested it in a primary school)
 - with 12-13-year-old pupils in one classroom in Reconvilier-Jura (“Storm2prim” – as it is a second improved version of this case that we tested in a primary school)
- The **Digalised Euglena case** was tested in two environments:
 - with one group of University students in Neuchâtel (“EuglDig1uni” – as it is the first version of this case and we tested it in the University context)
 - with 13-14-year-old pupils in one class in Le Locle-Neuchâtel (“EuglDig2sec” - as it is a second version of this case that we tested with secondary school pupils).

⁵ The scenarios implementations in the educational fields have been made by advanced students in psychology and education under the supervision of N. Muller Mirza. We thank them warmly for their collaboration and their rigorous contributions to the data gathering, analysis and reflection. Their enthusiasm provided a very important input towards the realization of this experiment. This text is therefore the fruit of the collaboration with F. Bonvin, and F. Stettler, A. Pylypenko, S. Moretti, S. Kaelin, Y. Benjelloul, E. Ndayiragije, L. Teodoridis, C. Miserez, F. Rohrbach, K. Vamavedan, N. Crélot, M. Nansoz, L. Lizano, N. Terrier, E. Fasan, S. Davin & M. Jeanneret-Atanasova. We also thank the teachers and the pupils who participated in this experience.

⁶ The storm case was developed by F. Bonvin & F. Stettler in the frame of the course « Argumentation and learning ».

⁷ A case called « Euglena » was initially developed by Osborne, Erduran, & Simon (2004b). In “Digalised Euglena” we took the main topic and structure of the scenario, and integrated the use of Digalo software.

Learning by argumentation and learning to teach through argumentation

If argumentation is conceived as “helping to recognize” the reasonableness of a position (Rigotti & Greco, 2004), and involves at least justification and negotiation mechanisms, it may be used by quite young children in some familiar and meaningful situations (Dunn & Munn, 1987). Its main features are, however, objects of development (Golder & Coirier, 1994). Everyday argumentation, made by children and adults, rarely shows sophisticated elaboration (Kuhn, 1991; Schwarz, 2001). In school, in spite of its potential for learning – due mainly to the fact that it involves verbal interaction (Mercer) and may lead to the social resolution of conflictive perspectives (Perret-Clermont, 1980 ; Baker, 2002) – argumentation is rarely used as a tool for learning. Working and discussing with teachers (or future teachers) on these issues could be an important beginning for a better understanding of this pedagogical method, but also of its difficulties and limitations.

At the University of Neuchâtel, we opened a course (from 2005 to 2007) for students in Education and Psychology, future teachers or researchers in education, or people who have teaching experience or are teachers themselves. This course, entitled « Argumentation and learning », had two main goals : presenting the psychosocial issues of learning by argumentation, and developing and testing argumentative activities in the sciences. After some introductory lessons on theoretical backgrounds in argumentation and learning, participants were invited to work in small groups and develop a scenario that they could implement in classrooms. Before the implementation, each scenario was tested among the participants and was modified following their recommendations.

For each case, we have thus chosen the following implementation process:

1. a first preliminary test of the case in a “secure” context, at University: the teacher-students involved in the research and implementation project were asked as a group to test one case; each of them had to play the role of a teacher (who presents the topic, asks questions, moderates the debate, gives feedback, etc.) or of a learner. This step was aimed at familiarizing the participants with the topic, the main steps and the activities involved in the role of a teacher and of the pupils, and at leading them to make some changes in the case according to their observations before its implementation in the field;
2. the second step was the implementation itself of the cases in class with pupils⁸.

Through this design, students experience different social and professional positions, those of learner, teacher, and researcher.

Five main interrelated steps structure the pedagogical syllabus of the University course:

- Theoretical and methodological contributions
- Collective work on elaboration of a « good argumentative scenario in sciences » (in small groups)
- The test of a first version of the scenario (among the students, in small groups)
- The test of the scenario with pupils in a classroom

⁸ Two courses have been conducted at the University of Neuchâtel by N. Muller Mirza, with some changes: the first one (2006) was more focused on how to develop an argumentative design in science with reflections about scientific reasoning and science development; and the other one (2007) on how to implement an argumentative design in a classroom. Both were conducted during one semester with about 25 students in 2nd, 3rd and 4th year in psychology and education.

- The writing down of the main results of data analysis and reflexive position about the work.

Some psychopedagogical points of departure for the Storm and Digalised Euglena cases

1. Learning objectives

The Storm and Digalised Euglena cases both focus on two kinds of learning objectives:

- *knowledge acquisition of specific contents in sciences* – according to the pupils’ age and their previous knowledge of the topic (for instance, for the Storm case: a better understanding of the main features of a storm; what is lightning; and for the Euglena case: a better understanding of what is a cell and what are the Euglena characteristics...), and,
- *development of competencies and communication strategies in enquiry and argumentation* (making reference to documents, referring to relevant information, grounding his/her perspective, taking into account the others’ perspectives, asking questions, putting assumptions into questions...).

The topics about the cells (Euglena) and the storms have been chosen as they both provide the opportunity for the learners to acquire knowledge about contents that are of interest in the science curriculum, and because they offer opportunities to develop rich interactive learning processes.

For the Storm and the Digalised Euglena cases, the pedagogical scenarios are phased and structured though individual, small group and classroom activities. The argumentation phase is one among several steps.

The design of the scenarios is grounded in a socio-constructivist approach, putting emphasis on the learner as an actor who is conceived as able to construct new knowledge in interactions. They also are developed on the basis of some of the previous results from research in argumentation and learning that shed light on the difficulty for children, as well as for adults, to engage in argumentation (Andriessen, Baker & Suthers, 2003; Golder & Coirier, 1994). These findings stress the importance of carefully designing the argumentative activity, and in particular, taking into account:

- the *cognitive* dimension (to make sure that participants have knowledge about the topic, in providing, for instance, pupils with opportunities to make reference to “scientific” information; to make sure that the information is understood, etc.),
- the *affective* dimension (framing the argumentation phase so that it is focused on content and not on the people; teacher’s presence in order to prevent interpersonal conflicts, etc.), and
- the *communicative* dimension (to agree on a “contract of communication”; framing a controversial and clear question for the debate phase; providing opportunities for interactions and confrontation of perspectives, etc.).

Our design choices are also linked to some authors’ claims about ICT tools that facilitate argumentation and learning (Andriessen, Baker & Suthers, 2003; Schwarz, 2001).

2. Digalo

Except for one version of the Storm case implemented in primary school, all the cases have been tested with Digalo as a mediation tool. In general, during the “argumentative phase” of the case one sub-group of learners worked via Digalo while the other one held an oral discussion.

Digalo seems an interesting technological tool for facilitating argumentation practices in the learning environment as it allows (Muller Mirza, Tartas, Perret-Clermont & de Pietro, 2007):

- keeping track of the discursive processes (learners can come back and reason about what has been said and why)
- supporting thinking processes in allowing the learners to write down and thus to make explicit and externalize their ideas
- taking time to reflect upon the arguments of the other participants
- justifying and grounding arguments (by means of the different windows of the software)
- sustaining articulation between arguments (with the use of the arrows)
- diminishing the face to face stress of argumentation, which is mediated at a distance by writing with Digalo, etc.

3. Sequence of phases

From these assumptions, and according to the topics and populations, we have adopted a main structure that involves a sequence of phases, articulating collective, small group, and individual works.

The main phases are the following:

- in order to be able to follow the possible development of specific knowledge, we first asked the participants, individually, to answer some questions at the beginning and at the end of the case; we will call these small questionnaires “pre-test” and “post-test” (but we are aware that the terms are not very appropriate). These questionnaires are also used as a tool for the researchers to see the « pre-knowledge » and representations the learners have about the topic at stake;
- a moment is devoted to provide some general information to learners in a class group about the topic at stake. The teacher uses a power-point presentation, for instance, and gives written documents, including the main information. This step is aimed at giving (or reminding of) some of the notions that could play the role of a “knowledge common ground” in the argumentative phase;
- the “controversial” question is presented to the group, for instance: is Euglena a plant or an animal? Does lightning touch the ground during a storm?
- Sub-groups are formed. Concerning the Euglena case, a “pro plant” cell group and a “pro animal” cell group were formed;
- Each group is invited to ground its argumentative position with the help of documents and of the teacher. They write down these points on a common sheet. This step should provide pupils with information that they will use as arguments in the debate phase. They are also asked to read texts and to learn to select relevant points in complex documents. This phase is also an interactive moment where the pupils are discussing together the relevance of their choices;

- The sub-groups meet for the debate phase, which is mediated by Digalo or orally. A “contract of communication” is discussed (each person may express his/her position; each person must be listened to; turns at speaking must be respected, etc.). The groups try to convince the other groups of the relevance of their respective position by grounding their own perspective and putting the others’ into question. This phase is expected to see participants confronting their perspectives, entering into socio-cognitive conflicts and argumentation processes – and possibly into learning processes;
- A discussion with the whole classroom is then organized by the teacher in order to answer questions, to synthesize the learning processes, etc.;
- The pupils are asked to respond to a post-questionnaire.

General background of the implementations

In the school contexts, the preparatory work for the implementation consisted primarily of contacting science teachers who were known personally by the researchers. Once the teachers gave their personal agreements, the educational board of the district, the school officials, the parents and other authorities were contacted for their official agreement.

It is interesting to note that the idea of implementing an argumentative scenario in their classroom was enthusiastically welcomed by the teachers. However, an argumentative approach does not appear to be well- established in the school contexts, but this general observation has to be confirmed. This kind of practice, however, seems strongly supported by the authorities. When discussing with the Neuchâtel school board director, he made reference to other experiences in sciences focusing on enquiry and debate practices that he wished to improve and develop, for instance the “Main à la pâte” program – initiated in France in 1996 by Georges Charpak, Nobel Prize in 1992 (<http://www.inrp.fr/lamap/>; <http://www.unine.ch/laquinzainedelascience/presentation.html>).

All the experimentations were made in collaboration with the school authorities and with the teachers. All the cases were presented to the learners by the student-teachers instead of the regular teachers.

During the preliminary phase with the teachers, the general frame of research was presented to them together with its objectives and modes of implementation in their classes. We discussed and negotiated with them the content of the scenario that would fit their program and their pupils’ expertise; the cases and their main phases were adapted according to their comments. A discussion was organized with the teachers after the case implementation to get their general feedback.

The Storm case

1. The main steps of the scenario

- 1) Individual pretest: (pupils are asked to respond to general questions about the storm phenomenon, for instance: What is a storm in your opinion? What are the main elements that constitute a storm? What are the main steps? How does a storm take place? How can we predict that a storm is arriving?)

- 2) Presentation of some information about the storm (by means of a power-point presentation)
- 3) Group elaboration (by taking into account responses to pre-tests, elaboration of groups in which pupils have diverse preconceptions)
- 4) Texts presented to the whole classroom about storms; each pupil individually reads them
- 5) Preparation of arguments in groups (group work): each group prepares an “argumentative map” (written) about some open questions. For example: Is a storm an electrical phenomenon? Are all clouds storm clouds? Is it windy when a storm arrives? Does lightning touch the ground? Are lightning and thunder linked?
- 6) Debate with Digalo or orally (about one or two open questions)
- 7) Individual post test
- 8) Plenary discussion (teacher and group work)
- 9) Feedback from the teacher.

After the trial of its first version, the case implemented in *Storm2prim* has been slightly redesigned. The main changes concern the documents given to the pupils, the formulation of the questions for the debate phase, and the ways of elaborating the working groups, in order to take into account different factors such as the different age of the population and the specific advices from the teacher.

2. Learning expectation

In the different classroom contexts in which we tested the Storm case, we have two-fold objectives to reach in terms of learning: acquisition focused on *scientific contents* concerning the phenomenon, and *competencies and communication strategies in enquiry and argumentation* (knowingly making reference to documents, referring to relevant information, grounding his/her perspective, taking into account the others’ perspectives, asking questions, putting assumptions into questions, etc.).

The scientific expectations are actually not the same for all populations according to their ages, however, as the topic is quite new in both contexts. We hope that the findings will show a better capacity to use ad hoc vocabulary (the name of the clouds, for instance), to differentiate between the main features of the storm, to articulate the different steps of the storm phenomenon (cloud, thunder, lightning, etc.), and to integrate the role of electricity in their representation of the storm.

As a complex physics and meteorological phenomenon, this topic may be a good opportunity to introduce discussion and argumentation in the learning process.

3. The Storm case in a primary classroom (Geneva)

Social context

The class in which this case was implemented had the following characteristics:

- 22 pupils of 9-10 years old;
- primary school (in this context it means that the pupils have a privileged relationship with one teacher who teaches them the main subjects in Maths, Sciences, French, etc.);
- mixed population according to their linguistic and cultural backgrounds.

Data

- The oral debate was audio-recorded

- Field notes of the researchers-teachers
- Pre- and -post questionnaires
- Argumentative maps (written)

Description of the implementation process

The teacher was known by one of the two student-teachers involved in the design and implementation of this case. They discussed with her the topic that would fit the school program and the pupils' interests. She had never practiced this kind of activity with her pupils and was very interested in the idea. Open-minded and very active in innovative pedagogical reflection and practices, she collaborated in depth with the student-teachers. She thought that the topic of a storm could be of interest to the pupils in her program. With her help, they designed the scenario (main steps, questions, documents, etc.), presented it to the pupils, framed and moderated the debates, etc. In between the two sessions, the teacher took 2-3 hours in order to read and work with her pupils on the documents.

The case was divided into three main phases, during three afternoons.

The *first phase* was devoted to the « pre-test » of the pupils' knowledge on the storm phenomenon. The student-teachers started by introducing themselves to the classroom and explaining their objectives. Then, they told the pupils what was expected of them. This involved their preparation of short notes and their collaboration throughout all the activities. The teacher thought that it was important to make the introduction in her presence so that the pupils would understand that this was not simply a new "game" but a serious activity in which they had to take part even if their usual teacher did not conduct it.

After the introduction, the student-teachers presented the topic that they would study in class: "storms". Without giving too much information, the student-teachers asked the pupils to give written answers to the question that had been written on the blackboard: "What does a storm mean to you?".

To help them in their reflections and in order to obtain the most accurate/complete information about their knowledge, after 10 minutes, the following additional questions were written on the blackboard: "What are the main elements that constitute a storm? What are the main stages of a storm? How does a storm take place? How can we predict that a storm is going to take place?".

Subsequent to this first phase, two groups of children, the "experts" and the "novices", were created based on the preliminary knowledge of the pupils, which had been evaluated through the answers that they had given in this first stage. The criterion used to divide the class into the two groups was the number of correct terms quoted. The student-teachers chose 9 criteria for selection: specific types of clouds (black, grey, heavy), rain, lightning (light, blinding lights), thunder (noise and loud noise were also accepted), violence, wind, electrical phenomena, temperature, meteorological/climatic phenomena. Furthermore, the groups that had been formed were reviewed by the teacher so she could inform the student-teachers of any other aspects that might hinder the experiment, such as social dynamics in the classroom or relationships between the pupils. The student-teachers were guided by the teacher's knowledge of the classroom social dynamics to place the pupils that they were unsure of.

During the days between the first and the second phase of the experiment, the pupils were asked to read in class or individually the documents that they had been given.

The second phase is the central moment of this experiment because the pupils have to debate among themselves. This phase therefore begins with small groups (for / against) who discuss controversial questions in order to elaborate an « argumentative map » in each group around the following questions: “Is a storm an electrical phenomenon? Do all clouds produce storms? Is it windy during a storm? Does lightning touch the ground? Are lightning and thunder linked?”. The discussions could be based on the documents-resources. The “argumentative maps” (which consist of the arguments elaborated by the group for each question) are written on large sheets of paper. The division into sub-groups (the « pro » sub-group and the « con » sub-group) was randomly made and was therefore not based on any criteria other than the desire to obtain two groups with similar numbers.

After the elaboration of the argumentative maps in each group, the oral debating started. The two sub-groups from each group were reunited to debate their divergent opinions. The « pro » sub-group had to defend the « yes » answers to the questions whereas the « con » sub-group had to defend the « no » answers. A certain number of communicative rules were established with the pupils so that the debate would run smoothly: to let her/his interlocutor finish expressing her/his idea, to respect the order of speaking, to explain why one thinks what we express, etc.

The third phase was aimed at collecting answers to the post-test and to answering the pupils' questions. The pupils were asked the same questions as the ones in the first phase: “What does a storm mean to you? What are the main elements that constitute a storm? What are the main stages of a storm? How does a storm take place? How can we predict that a storm is going to take place?”. Then, according to the teacher's recommendations and wishes, the student-teachers gathered the pupils in the lecture hall so that there would be more space for a discussion. This stage was prepared in close collaboration with the teacher, who made a number of suggestions which were interesting from a didactic point of view. The student-teachers started by asking each pupil in turn if they had any unresolved questions concerning the topic. This was in order to know which elements remained unclear to the pupils and so that the student-teachers could in future adapt the explanations they gave in the first stage of the experiment. Subsequently, the student-teachers started a discussion around the questions that had been asked because their role involved being both sources of information and provoking the debate. Indeed, before answering the questions, the student-teachers asked the other pupils their opinions. In the third phase of the experiment, the student-teachers suggested a more game-type activity (e.g., a crossword) around the topic of storms in order to answer the questions that still remained unclear. Finally, the student-teachers asked the pupils what they had thought of the activity by asking the following questions: “Have you learned something? If the answer to this first question is yes, what did you learn? Have you enjoyed this way of working? What did you or did you not like?”

4. Some results of the experiment

The teacher's point of view

The teacher, who was in charge of the classroom, found the whole activity very interesting. However she was dubious about the difficulty of managing differences in levels of knowledge. She observed that whilst the more eager pupils readily participated in the debate, others were less involved. She also saw that some of them had a difficult time writing down their answers and was aware of the importance of choosing textual resources of interest that were not too difficult for the age and levels of her pupils.

Pupils' point of view

Many pupils expressed their interest and motivation saying that the activity was “cool!” and that they had “learned a lot” (new vocabulary, new knowledge about the storm phenomenon). Interestingly enough, they were very happy to work in groups, to “learn from each other,” saying that “we can listen to what the others say, develop and compare”.

Learning processes: knowledge construction and argumentation

What can we observe in terms of learning and argumentation processes from the data gathered?

First, by comparing responses to the pre- and post-questionnaires to the question : “What do you think a storm is?” we can observe three main elements :

- a general increase in the ad hoc vocabulary: at the end of the activity it seems that the pupils were more able to use words like “cumulus-nimbus” rather than “black cloud”, or “lightning” rather than “light”, or “thunder” rather than “a big noise”;
- a more complex understanding of the storm phenomenon: the storm is less often reduced to only lightning in the post-questionnaire; lightning is one of the components of the storm;
- a better articulation between the different features of the storm and the causality relationships that exist among them.

Here is a nice example that shows the conceptual development from a pupil who wrote :

Pre-test : « I think that a storm is the meeting between hot and warm. When they meet it makes a big « boom » ! It is like a battle. When one of the two is winning the storm stops ».

Post-test : « A storm is an electrical phenomenon with lightning and thunder. One knows that a storm is arriving when there are cumulus-nimbus... ».

From the transcriptions of the oral debate between the « pro » and « con » groups, it is interesting to observe both groups working hard in order to give elements, for example, to the question « is the storm an electrical phenomenon ? ». One « con » group, for instance, tries to convince the other group by developing an interesting strategy : they divide the storm into its basic elements. The storm is not an electrical phenomenon as the clouds are not electric, as rain is not, as what is surrounding a storm is not, as there is not any “battery” inside it. The “yes” group makes reference to the texts they read and says, for instance, that Benjamin Franklin shows electricity by means of a kite: “it is written that the movements of electricity that are accumulated inside the clouds provoke electricity”. Pupils at this age thus seem able to justify their positions, making reference to texts, to

personal experiences or to what adults have said, or even to funny “evidence” when they think that they have to justify a strange affirmation.

They also show that sometimes they can take into account what has just been said in a more or less complex co-construction process, like in these examples:

Group No (15): the clouds are not electrical
 Group Yes (16): we have said that the clouds make electricity!
 Facilitator: we are in a mess, aren't we?
 Group No (18): It is not true they do not make electricity!
 Group Yes (19): If...
 Facilitator: why do you say “if” Sasha? Angela, an idea?
 Group Yes: it is written that the movements of electricity that are accumulated inside the clouds provoke electricity
 Facilitator: then?
 Group Yes: then there is electricity in the clouds

Or in this other example:

Group No (29): the clouds are made of vapour of water, thus it is not electrical
 Group Yes (30): yes, but after it becomes electrical
 (...)

 Group No (34): yes, the clouds inside, there is only vapour of water
 Group Yes (35): but after in the clouds, it still makes electricity
 Facilitator (36): after what?
 Group No (37): but how can a cloud transform itself into electricity?
 Facilitator (38): yes
 Group No (40): when I touch vapour of water I am not electrified
 Group Yes (42): but no, but the vapour of water it goes up and makes the cloud and inside the cloud it makes electricity...

Reasoning by argumentation seems quite difficult for these young participants, and the teacher has an important role to play in reframing, making socio-affective regulations, reformulating or helping to develop links among elements of the topic under discussion.

5. The Storm case in a primary classroom (Jura)

Social context

- 24 pupils of 12-13 years old;
- primary school;
- the regular teacher is one of the student-researchers who took part in the research (but she did not play the role of the teacher in her own class)
- The researchers (a group of 6 advanced students) took the case as it had been tested in Geneva and adapted it to their specific context. They thus played the role not only of designers (in particular, they prepared a new power-point presentation) but also of teachers in the classroom.

Data

- Field notes of the researchers-teachers
- Pre- and post-questionnaires

- Argumentative maps (written and Digalo)

Description of the implementation process

The case was implemented in a primary classroom in which the regular teacher is part of the research (but she did not play the role of designing and giving the lesson about the storm in her own class). She is interested in activities in which pupils are involved in group work and that are enquiry oriented. She took 1-2 hours with the pupils in order to read and discuss the documents about storms.

It took two sessions of 45 minutes each to implement the case.

6. Some results of the experiment

Teacher's point of view

The role of the teacher in this argumentative setting was quite unusual. In working groups, for instance, she had to be aware of letting everyone have his/her say and not letting some pupils be the cause of jokes when they try to say something.

Pupils' point of view

With Digalo, pupils felt at ease but faced some problems in writing down their ideas. Writing in Digalo took time and slowed down the activity. Having four people at one computer was also an additional difficulty. The children appreciated discussing their ideas using a computer, because they could clearly visualize the argumentative map. They enjoyed Digalo, and this tool, integrated into a learning setting, stimulated their motivation.

Learning processes: knowledge construction and argumentative processes

Construction of knowledge

The post-tests revealed that the majority of the pupils had gained new understanding of the Storm phenomenon, new understandings elaborated either during the debate and/or during their readings of the texts. More than half of the pupils answered in a more complete way in the post-test. They added the elements of the lightning and the flashes to their answers. They regarded these two elements as being important for defining a storm. Moreover, the word "thunder" also appears more in the post-tests. Several pupils evoked this topic in their discussion when they had to make the distinction between the lightning and the flash.

Although it is difficult to see whether the pupils really included/understood the formation of a Storm, we can claim that there is construction of new knowledge compared to the first meeting.

Argumentation

The pupils argued by referring to knowledge or their own experiences, which they tried to synthesize and write down. The pupils were not familiar with argumentation. Indeed, it was not easy for some of them: to argue does not consist merely of expressing or communicating opinions, ideas, proposals, desires, projects, etc., but also of justifying them and grounding them in reasoning, with a critical attitude towards statements made by the others and oneself.

During the debate, we saw that the pupils tried to use the arguments they had found in favour of their position during the preparation phase. They were able to take into account

the arguments from their partners, but it was quite difficult for them to find new arguments during the mediated discussion.

The Digalised Euglena Case

1. The main steps of the case

This case is constructed around the Euglena cell, which shows interesting “ambiguous” characteristics. It has both plant and animal properties, as it shows, for instance, an autotrophic property (like plants that “nourish” themselves via photosynthesis) and, under certain circumstances, a heterotrophic property when absorbing and digesting dissolved organic matter in the water (like animals). The Euglena cell is part of the protest kingdom of living that gathers all the mobile and unicellular living beings.

In teaching science, this kind of phenomenon is of special interest. Starting with an ambiguous object can lead learners in science to explore the specificities of the categories that are linked to the phenomenon. It also may allow participants to enter into a dialogical work, which is at the heart of scientific activity.

Throughout the sessions, the pupils work individually and in small groups. They are led to develop an enquiry approach: by finding answers to some scientific questions, by looking for arguments from textual resources and by defending their points of view during the argumentative phase. In particular, they are asked, in small groups, to prepare and defend one position: “Euglena is a plant cell or an animal cell?”.

Because the scenario is made up of different steps, an argumentation phase needs to be prepared. After a pre-questionnaire aimed at a better understanding of the learners’ pre-existing knowledge and representations of the cell topic, the teacher presents the main features of the animal and plant cell, and the specificities of Euglena. Small groups are formed: one will defend the position that Euglena is a plant cell and the other the position that it is an animal cell. During an “intra-group” phase of preparation of their main arguments, each group will have some textual resources at its disposal. They first prepare an “argumentative map” (listing their arguments on a sheet of paper) that will serve as a tool for the debate phase. The debate, mediated by Digalo, follows: both groups try to convince the other and/or to reach a common understanding. Finally, the teacher discusses the results of the debate and presents the scientific categorisation of this single cell. The learners are asked to fill in a “post-questionnaire”, with the same questions as in the “pre-questionnaire”. The various steps are structured in the following order:

- Each pupil gives answers individually (pre-test)
- In classroom and/or at home, individual and/or in groups: reading of texts about the animal cell and the plant cell
- In small groups (groups of pupils are defending the position that Euglena is a plant cell, and others are defending the position that it is an animal cell): preparation of arguments in each group
- In groups (one group “pro plant” debating with one group “pro animal”): debate with Digalo (or orally)
- Post- questionnaire (individually)
- Plenary discussion and feedback.

2. Learning expectations

The contexts in which we tested the Digalised Euglena Case are different in terms of age (pre-adolescent and young adults) and in terms of institutional setting (biology classroom in a secondary school and a psychology lesson at University). We expect, however, that the young adults, although more experienced in the argumentation strategies, will not be able to mobilize as much knowledge about biology as the pupils in the biology classroom.

The scientific contents that we hope will be grounded and developed by the participants are linked to the cell domain: a relevant use of the terminology related to the various elements of a plant and animal cell, and an understanding of their main functions. We also expect strategies of inquiry and argumentation that “may develop throughout” the scenario.

More precisely, learners, by exploring the characteristics of the Euglena cell, are expected to acquire new knowledge about:

- the main features of an animal and a plant cell;
- the main differences between both;
- the existence of a class of organisms that is neither animal nor plant (and thus make them aware that there are more living kingdoms than the 2 we know about...).

3. The case in a University setting

Social context

- 25 students in a course of Psychology & Education at University of Neuchâtel
- Two student-researchers designed a new version of the case elaborated by Institute of Education of the University of London (Osborne, Erduran, & Simon, 2004b)
- they thus played the role of designers, teachers and of researchers as they recorded and analyzed data gathered in this frame.

Data

- Audio records
- Digalo argumentative maps (figure 1)
- Field notes
- Pre-and post-questionnaires.

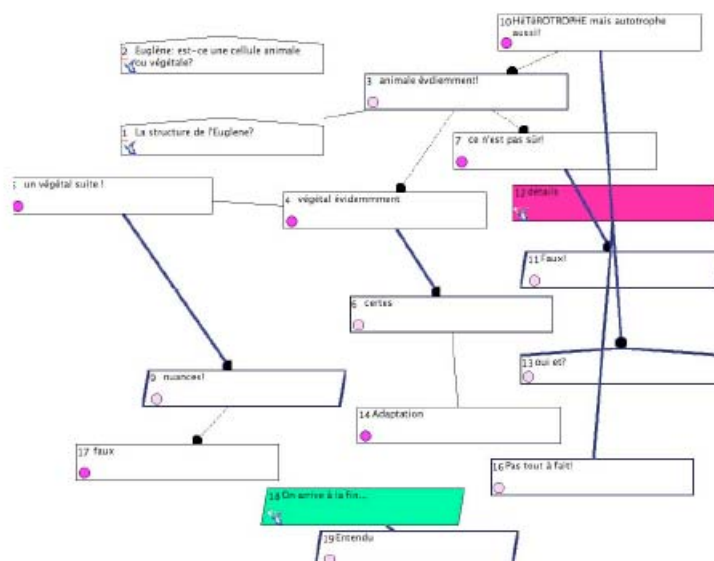


Figure 1: University students Argumentative map with Digalo

Figure 1: University students Argumentative map with Digalo

4. Some results of the experiment

What do participants think about the design of the case?

Rather positive appreciation: «I found this activity interesting, trying to find arguments and counter-arguments opens for discussion of the tricky problem of Euglena. I would like to know more about it.» [J'ai trouvé cette activité intéressante, le fait de chercher des arguments et des contre-arguments ouvre bien les champs de la problématique de l'euglène. J'aurais envie d'en savoir davantage].

Learning processes: knowledge construction and argumentation

Data show that learners actualise knowledge not only in the domain of the cell, and the Euglena in particular, but also in argumentative practices, and that both kinds of knowledge are actually interconnected.

In terms of vocabulary, the participants used more of the ad hoc scientific vocabulary at the end of the test; we observed an increase in the specific vocabulary from pre- to post-questionnaire:

In the pre-test, students used common sense and did not generally use a scientific vocabulary in order, for instance to, define what an animal is: “L’animal est un être vivant, comme les mammifères par exemple, il se déplace, il vit, tandis que le végétal est aussi vivant, mais ne bouge pas, comme les plantes par exemple” [The animal is a living being, like the mammals for example, it moves, it lives, while a vegetable is also alive, but does not move, like plants for example].

In the post-test, the contents were more focused and better articulated, with the use of more scientific terms.

In the university setting, participants showed abilities to focus on relevant topics in order to go further into the debate, responding to the question. They formulated arguments linked to the following domains:

- internal structure (vacuole; chloroplast)
- ways of nourishing (hetero/autotrophy)
- external structure (membrane)
- ways of moving (flagella).

In terms of argumentation, we can observe students playing their dialogical position (animal vs plant) as it was suggested by the moderator; it means that they formulate arguments related to the position they have to defend, and stay focused on the task. They articulate their own claim with the one or the other, and take into account their opponent's perspective.

It is interesting to observe that the groups developed their argument in taking explicitly into account what was said by the other group, like in this intervention from the "animal group" (University students): "comme vous le soulignez très pertinemment, la vacuole est CONTRACTILE. Encore une preuve tangible de l'animalité de la bestiole." [as you have underlined it, very relevantly, the vacuole is CONTRACTILE. This is a tangible proof of the animalistic character of the small beast] (t.p.9) – this non-valid claim is countered by another intervention from the plant group: "la cellule animale n'a pas de vacuole du tout!!!" [the animal cell doesn't have a vacuole at all!!!].

We can also shed light on some interesting interactions where the groups do not argue in an agonistic way, but try other strategies and explore, in a collaborative way, the nature of the object they are discussing: "Vous dites que le flagelle et la vacuole sont typiques [de l'animal], mais pouvez-vous dire en quoi avec plus de détails? Que dire du fait que la vacuole est un élément partagé à la fois des animaux et des végétaux?" [You say that the flagella and the vacuole are typical [of an animal], but can you explain why with more details? What can we say about the fact that the vacuole is a shared element of both animals and plants?"] (t.p.12). Or, in this exchange, which has a kind of inquiring spirit, when the plant group writes: "On ne sait pas en quoi la membrane est faite. Si elle est faite en cellulose, il s'agit d'un végétal." [one does not know what the membrane is made of. If it is made out of cellulose, it is a plant"] (t.p.7). To which the animal group responds: "vous avez mal compris, la cellule végétale n'a pas de membrane du tout!(...)" [you did not understand properly, the vegetable cell has not got a membrane at all!] (t.p. 11).

At the end of the discussion, the groups in University reached the conclusion that *Euglena* "is not a normal feature" ["sort de la normalité"].

5. Digalised *Euglena* in a secondary classroom

Social context

- 20 pupils of 15-16 years old;
- secondary school level;
- biology lesson
- The researchers (a group of 7 advanced students) took the case as it had been tested in the University setting and adapted it to their specific context. They played the role not only of the designers but also of the teachers in the classroom.

Data

- Field notes of the researchers-teachers

- Pre- and post-questionnaires
- Argumentative maps (written and Digalo) (figure 2)

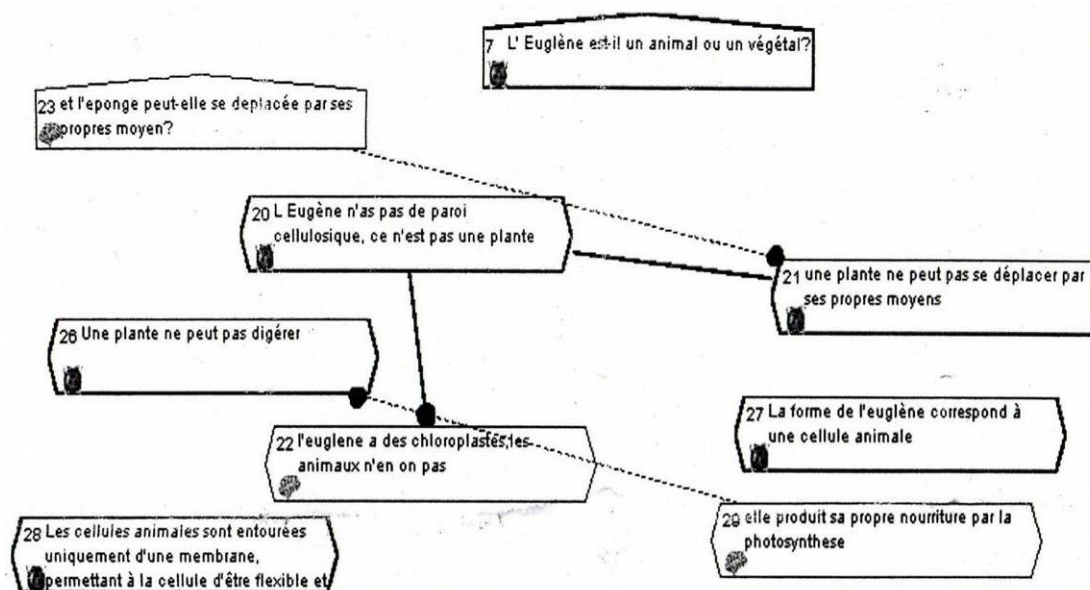


Figure 2: Secondary classroom Argumentative map with Digalo

Description of the implementation process

The biology teacher had prepared her pupils by giving 2 lessons about the cell topic before the case implementation. The pupils had, therefore, some pre- knowledge at the beginning of the case.

The implementation of the case took 45 minutes. After the student-teachers had introduced themselves to the class, they asked the pupils to take an individual written pre-test in order to establish their knowledge. The student-teachers told the pupils that the pre-test was not a test that would be marked and had nothing to do with the evaluation of their school work. Then, they explained the next stage of the experiment, which would involve working in sub-groups and participating in debates. Afterwards, the student-teachers introduced the topic and handed out documents that explained the particularities of a plant cell, an animal cell and the Euglena. The student-teachers had considered projecting a series of Powerpoint presentations but abandoned the idea through lack of time. The student-teachers then asked the pupils the following question: « Is Euglena an animal cell or a plant cell ? » and, as previously advised, the student-teachers divided the class into two groups who had to defend each viewpoint. Two groups of five pupils were formed. One group would work with Digalo and would be supervised by three student-teachers, while the other group would debate under the supervision of another three student-teachers.

Since their arrival in the classroom, the pupils had already divided themselves « naturally » into two groups, as five pupils were sitting on the left side of the classroom and the other five on the right side. In addition, one group seemed much more vocal than the other, so, to gain time, the student-teachers kept this « natural » division. They sent the quieter group to work on Digalo while the other five pupils took part in an oral debate.

The group that took part in the debate was asked the following question : “Is Euglena an animal cell or a plant cell ?”. The student-teachers divided the group into two sub-groups. Three pupils were put into the pro-animal group and two pupils were placed in the pro-plant group. The student-teachers then handed out the documentation that supported each position. The pupils were left for ten minutes so that they could find arguments that they would be able to use during the actual debate. The role of the student-teachers was to frame and animate the debate. They had decided that the debate would last approximately fifteen minutes, which was an easy target to fulfil.

The group that worked with Digalo was also divided into two sub-groups : three pupils were put into the pro-animal group and two pupils into the pro-plant group. Each sub-group was then placed before a computer in order to be able to debate via the Digalo program. Before starting the debate, each group was given five minutes to prepare some arguments to support its position (pro-animal or pro-plant). The student-teachers also explained how the Digalo program worked. The debate via Digalo then took place for fifteen minutes. At the end of the debate, the pupils sat a ten minute post-test so that the student-teachers could establish how much the pupils had learnt.

Finally, the student-teachers conducted a general concluding discussion with the class during which they talked about the particularities of the Euglena cell with the help of a Powerpoint presentation.

Teacher’s point of view

The teacher in charge of the classroom was very interested in the project and felt that it was a pity that the pupils could not spend more time on it. She also regrets not having enough time to use debate and argumentation settings in her curriculum (she has only 1 period per week of biology with this group). She wants to come back to the Euglena topic later on in the year.

Pupils’ point of view

The pupils felt at ease. They generally seemed very pleased with this experiment.

Learning processes

The pupils were able to use the *ad hoc* vocabulary (for defining a cell, for instance), from the beginning of the scenario. But it seems that they have discussed among themselves and made reference to their notes when answering the pre-questionnaires...

In the argumentative maps, pupils formulated arguments linked to the following domains:

- internal structure (vacuole; chloroplast)
- ways of nourishing (hetero/autotrophy)
- external structure (membrane)
- ways of moving (flagella).

Thus they were focused on the task and used relevant concepts in order to explore and construct knowledge about the phenomenon.

As for *argumentative practices*, we can observe from our data that in the Digalo mediated debate, pupils played the dialogical role (Plant vs Animal). They started by referring to the specificities - following the position of their sub-group - of either the animal cell or the plant cell (“Euglena has chloroplasts and animals do not” (22)).

We also can observe that the Digalo shapes are well interconnected by means of arrows, showing an effort to make links between the interventions. However, the arrows show more of a preoccupation with arguing in order to attack the other's position or ground the other group's, rather than trying to have a better understanding of the limits of an argument.

We can read for instance:

Animal group: "Euglena n'a pas de paroi cellulosique, ce n'est pas une plante"
[Euglena doesn't have any cellulose wall, it is not a plant]

Plant group: « Euglena a des chloroplastes, les animaux n'en ont pas » [Euglena has chloroplasts, animals do not have any].

The reasoning is interesting and valid as the participants seem to say: if Euglena is a plant, it must have a cellulosic wall like all plants – since it does not have one, then it is an animal; this argument is countered by the other group, which seems to say: if Euglena were an animal – as you think – it would not have chloroplasts, so it is a plant.

They take into account the perspective of the opponents. In the secondary school classroom, we can observe an interesting argumentative strategy: the participants generally do not explicitly give arguments for their own position but attack, in an anticipatory move, the position of the other. Like here:

Animal group: "Une plante ne peut pas se déplacer par ses propres moyens" [A plant cannot move by its own means] (21)

Intervention that is counter-argued by the plant group, which claims:

Plant group: « Et l'éponge peut-elle se déplacer par ses propres moyens? » [And can a sponge move by its own means?]

Plant group: "les cellules animales sont entourées uniquement d'une membrane permettant à la cellule d'être flexible..." [the animal cells are surrounded by only one membrane which allows the cell to be flexible] (28).

Some general observations

During the pre and post-questionnaires the pupils respond to the questions with the help of friends and look at the sheets of their neighbour, as it was a sort of examination. It is interesting to observe a relationship between being at ease with the technical use of Digalo and involvement in the argumentation activity. The slowest students with Digalo were also the ones who hardly found arguments against the other group. The playful dimension seems a positive factor that helps the students to get involved in the learning activity.

Lesson learned and educational implications

1. Some difficulties encountered in the tests, and ways to improve the cases

- Lack of time is the most important limit of these tests: learners did not have enough time to discuss and reflect on the activity and their argumentation; a longer phase must be dedicated to a conclusive feedback by the teacher at the end of the scenario;
- In order to avoid the agonistic tendency to debate between two contradictory positions, the design should end with a final activity where

all the participants are invited to share the same objective (Jackson & Jackson, 1989);

- Assessment-evaluation: when and what to evaluate (from a teacher's point of view) remains an important question (that has not been addressed enough in our tests).

2. Contributions from the tests of the cases

In spite of some limits of the cases, it is interesting to see that learners were able to⁹:

- focus on the task and play the role they were assigned;
- use a scientific vocabulary that was made on purpose;
- articulate concepts – or try to;
- make reference in a relevant way to empirical data extracted from textual resources;
- mobilize argumentation skills and construct knowledge in interaction at the same time (“participant exercises his/her argumentative capacities in constructing knowledge with his/her adversary” (Douaire, 2004)).

Some of the usual difficulties of argumentative activities in an educational setting – mainly the difficulty of entering into an argumentative dialogue and weak argumentation – appear less apparent here¹⁰.

Two main reasons (as hypotheses) may explain our observation:

- a “controversy” modality added with a “role playing” modality: learners have to try to find relevant information and resolve a controversial question through dialogue. Many studies have shown the efficiency of this type of communication setting (for instance, Johnson & Johnson, 1989, 1995a); that is, it is not really the learner's own opinion that is at stake but that of the “position” s/he is assigned to. In that way, fear of entering into an interpersonal conflict might not be as strong (see also Muller Mirza, Tartas, Perret-Clermont & de Pietro, 2007);
- Digalo's functionalities can also be seen to facilitate argumentation practices – they allow learners to formulate claims, make reference to them, and to articulate them. However, some technical problems sometimes occur that render its use difficult or time consuming.

The cases we have tested and analyzed in this text show interesting findings and open new questions for researchers in education and for the teacher who wishes to implement them in his/her classroom. We list hereunder several of them:

- The status of “argumentation”. It becomes clear from this explorative research and others that argumentation can hardly be considered as a set of skills and rules that would be defined *per se* independently from the social, technological and institutional context in which it is used, and independently of a specific content. We have seen that even rather young pupils are able to enter into a dialogical reasoning about some complex physical phenomenon. Justification by means of

⁹ This scenario could be adapted for older pupils in the frame of history of sciences for instance: it could be interesting, on the basis of the Euglena scenario, to develop the role of categorisation in science, the way science is evolving, etc.

¹⁰ However, we have to be cautious: the research design is still in an exploratory form; we have access to little data, mainly the argumentative maps and the researchers' notes.

scientific features and articulation of concepts is observed in the argumentative maps through Digalo. However, we have to be aware of the complexity of the “psychology of argumentation” in science. One does not argue on any topic with just anybody anywhere. It seems important, for example, that the individuals who engage in this way of communicating and learning can feel in a secure frame, as debating is a risky activity for at least three reasons that are probably interrelated: for a relational reason (if I do not agree with my friend will s/he stay my friend?), for an epistemological reason (if my opinions and beliefs are put into question, what is right? Who is right? What is the truth?), and for an identity reason (if my opinions and beliefs are put into question, is it my own perception of myself, my identity that is at stake: who am I? How am I in an “uncertain” world?). And in the everyday practices of scientists, if argumentation can be located in different places¹¹, do pupils feel at ease questioning topics that have been the object of study by “scientists” for decades?

- The personal position of the learners towards the topic under discussion. Some lines of research are studying the role and the impact of the personal beliefs of the learners on learning. About some topics, as for instance, natural selection, teachers sometimes puzzle over: are the difficulties faced by the pupils due to the inherent complexity of the topic or due to the personal perception of the conflict between science and their religious beliefs, or is it due to some combination of the two? Perspectives suggest that if learners recognize and become aware of the conflict between their existing knowledge and the scientific conception, conceptual change is possible, under certain circumstances (Sinatra, 2003). In argumentation activities, personal views are central when learners are asked to explicitly state their own perspective on an object. In our designs, we made the pedagogical choice to avoid this situation and to assign a position (pro or con; Plant or Animal...) to each participant, whatever her/his personal position. However, this dimension remains an issue to keep in mind when implementing an argumentative activity. In a more general discussion, the epistemic beliefs about sciences, their evolution, the status of hypothesis, truth, theories, etc., are of a central interest, both from the learners’ and the teachers’ points of view. It is obvious that the pedagogical choice of the teacher in using an argumentative activity for teaching science is linked to a view of science defined in terms of trying to construct and resolve problems in specific theoretical frames rather than “discovering” things that have been hidden since the beginning of the world.
- The role of the teacher. In our design, the place of the teacher is not in front of the classroom yet her/his role is central (Lambolez & Perret-Clermont, 2003). S/he not only has to mediate (give some scientific information and cues, suggest readings, ask counter-argument questions...); but also to moderate (ask questions, guide the discussion, help to focus, etc.) the cognitive and discursive activities. S/he is the guardian of the frame, in its cognitive and relational dimensions. At the end of the activity it is important that s/he concludes the activity both at the content and at the relational levels: to remind the learners of the meaning and the finality of the activity, come back to the main points and the process of the

¹¹ There are arguments about what kind and what amount of data to collect (for instance whether the data will be valid and how much are needed to make them reliable); there are arguments about whether a given model is a satisfactory interpretation of the data (for instance, why the Bohr model of the atom is not a satisfactory model); there are arguments about the interpretation of data (for instance, do the rising levels of CO² mean that the global temperatures will rise)? (Osborne, Erduran, & Simon, 2004b).

discussion, and give the “scientific” position(s) on the topic under discussion, and also to discuss what happened during the dynamic of the discussion;

- The role of the software and its use. Our observation shows that Digalo is perceived as quite an easy to use and friendly tool. However, it is important not to underestimate the technical constraints of its use before, during and after the activity (setting up server, connections, firewalls, availability of the computer room and of the technicians, teacher’s and pupils’ familiarity with computers, configuration of Digalo, etc.). In our experience, it seems that Digalo may be used by the participants as a tool that to a certain extent leads them to externalize their thoughts and makes them “available” not only for the others but also for themselves. Its use also seems to be a motivational factor as it is still quite unusual for the pupils to use the computer in science classrooms and because of its interactive and synchronous functions.

For many years now, educational psychologists have agreed that knowledge is not acquired by transmission alone, but by (co-)construction. By putting the learners in argumentation settings, we proceed a step further, following scholars who claimed that learners can be the agents of their own learning: “It is a fundamental tenet of our theory that students have a right to understand, evaluate, and orchestrate their own learning” (Brown & Campione, 1994, p. 270). In the kind of design we have tested, the learner does not behave as a receptacle of prior knowledge but as an actor who is able to act seeking relevant information, making hypotheses, agreeing to be countered, who can reflect upon his/her own productions as well as upon those of others. The learner can thus experience a decentration and a reflexive position that may lead to a more meaningful and grounded learning.

8.3 Case C: “Why does it balance”? The Tightrope walker

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Introduction



In this paper, we will present the research we have carried out to elaborate and test a didactic scenario around the concept of balance in physics. We will first describe the initial problem and the didactical scenario which we have elaborated. Then we will present the experiments which were carried out at the University of Neuchâtel (in part 1) and at the Alta Scuola Pedagogica of Locarno (in part 2). In the conclusions, we resume the main observations and we give some recommendations for new implementations of the scenario in other contexts of teaching.

The problem

To keep one's balance or not is a concrete experiment which is related to the everyday life of the child; this experiment relates to the body (what child has never heard this piece of advice : "don't lean over too much or you will fall down! ") as well as to the objects which are used, for example, in the early and difficult activity of piling up studs to build a tower.

To go beyond the child's experiences and intuitions in order to explore systematically the conditions of equilibrium, we have selected a particular physical problem: the children have to make tightrope walker figurines which keep their balance.

In the first phase, a few tightrope walker figurines made with simple materials are presented to the children. They are asked this initial question: "Why do some of them keep their balance and some others do not?" The children are given the materials so that they can build tightrope walker figurines and test whether or not they keep their balance.

Our hypothesis is that such a situation stimulates the pupils to engage in exploration, construction, reflection and argumentation; these behaviours all contribute to the construction of the understanding and conceptualization of new physical phenomenon.

This situation has the following features:

Play situation. Although this is a situation requiring the resolution of a problem with a didactic aim, our situation presents a play aspect. Let us note that it will be important to take this play aspect into account in our analyses. It refers more clearly to a play situation than to a didactic task conceived for a science lesson. Indeed, the play aspect certainly helps the pupils to engage in the concrete task of construction, but it is also likely to make

it difficult for the children to mobilize their school knowledge when they try to understand the physical laws in question.

Intriguing. Another characteristic of the situation is its surprising aspect. It is intriguing to observe a complex object in a situation of balance when this is not necessarily expected. The difficulty for the children to anticipate with assurance which are the configurations of balance or of imbalance (because they do not understand their conditions) creates cognitive conflicts which are the sources of discussion and reflection among the pupils. In this situation, the non- predictability and uncertainty implies the awakening of curiosity. It is a good starting point for stimulating an activity of questioning and systematic experimentation of the factors concerned.

Reflective. The situation invites the pupils to handle simple materials to build by themselves various configurations of the tightrope walker in balance. Finding a state of balance can be achieved by practical intelligence, by trial and error, and by successive adjustments of the materials in order to obtain balance. Indeed, practical intelligence makes it possible to find balance intuitively. The activity of conceptualization comes afterwards to account for what was obtained on the level of concrete action. From this point of view, our situation is closely related to the tasks studied by J. Piaget in his book « Réussir et comprendre » (1974).

Complex (implies several physical concepts). The question of equilibrium was studied in many works from a psychogenetic and a didactic point of view. Several studies used a mathematical balance or mobiles hanging from wire (in the form of a succession of balances). However, our problem distinguishes itself from the case of the mathematical balance because it does not offer a purified or a simple modelization of a physical law (the physical moment), but proposes a concrete situation which intertwines several concepts of physics. (In this particular case : the physical moment, the centre of gravity, the stable and unstable balance). This overlap of several concepts certainly makes the understanding of the problem more complex, but it might induce an investigation and a more open argumentative activity.

Our didactical scenario

The aim of our scenario is to confront the pupils with the initial question: « Why does the tightrope walker keep its balance or not ? » and to invite the pupils :

- to express hypotheses
- to explore and try out the role of the variables concerned
- to discuss and to argue their own explanations
- to develop (according to their cognitive level) a primary understanding of the physical principles concerned:
 - physical moment,
 - centre of mass (gravity)
 - stable/unstable balance

The scenario includes the following phases:

Phase 1: Observing and discussing

The pupils are invited to observe a set of different tightrope walkers (that have different colours, materials, size, weight, etc.). Then the teacher selects two tightrope walkers (one

that keeps its balance and one that does not) and shows them to the pupils. They have to answer (orally or in writing; individually or in small groups) the following question: « Why does one of them keep its balance and the other one does not? ».

Finally, the teacher asks the pupils about the other tightrope walkers. They have to anticipate whether they will keep their balance or not and to present good reasons for their answers.

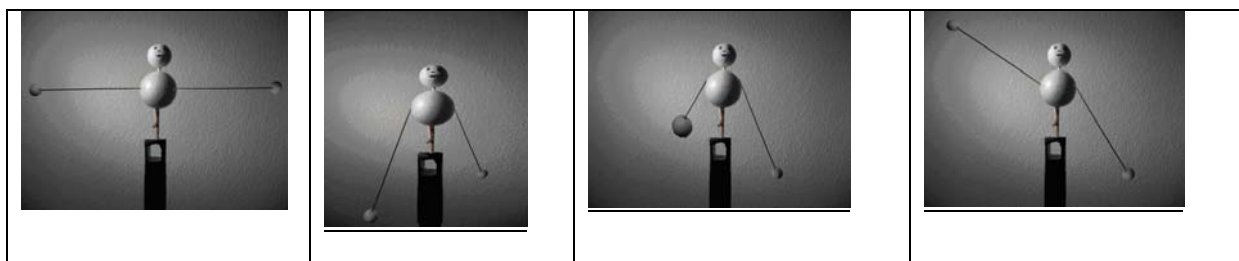
Phase 2: Building up a tightrope walker

The pupils have to build up a tightrope walker figurine by themselves using the materials presented (wooden or iron sticks, polystyrene or cotton wool balls, etc.). The aim is to make the man keep his balance.

Phase 3: Evaluating the conditions of the phenomenon

Several pictures are shown to the students. They have to anticipate orally (individually or in small groups), what will occur : « Will it keep its balance or will it fall down? »

Examples of pictures:



Phase 4: Analysing some arguments

A set of different written arguments is presented to the students. They have to decide, in small groups, which ones are right and which ones are wrong.

To make the tightrope walker keep his balance, you have to...

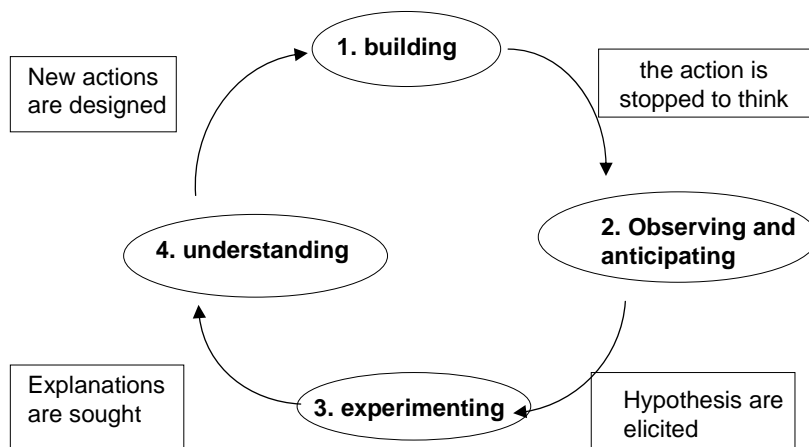
... put sticks which have the same length	right?	wrong?
... put short sticks	right?	wrong?
... tilt the sticks the same way	right?	wrong?
... put weights on the extremity of the sticks	right?	wrong?
... put light weights	right?	wrong?
... bring the tightrope walker to a standstill	right?	wrong?
... make sure that the man isn't too heavy	right?	wrong?
... make sure that the man's leg isn't too short	right?	wrong?

Phase 5: Collective discussion and synthesis

Here, the aim is to answer collectively the following questions: « What plays a role in making the man keep his balance? » and « Which are the main conditions? ». The collective discussion has to contain the following notions: gravity, force, balance (stable/unstable).

The « grammar» of the scenario

Our approach aims at establishing a circular move from the concrete activity of construction to the activity of progressive conceptualisation of the problem. This sequence can be represented by the following diagram. The succession of activities and processes represents, in a way, the «grammar» of our scenario.



The scenario is also characterised by the use of multiple representations of the given problem. Indeed, on the way, several types of supports are introduced to deal with the problem of balance: material, diagram, photographs, texts, and simulation of the tightrope walker on the screen.

Finally, another dimension which also structures the scenario is the alternation of the individual activities and the collective activities or activities in small groups.

Part 1 : experiments carried out at the University of Neuchâtel

We will successively present the experiments we have completed at the University of Neuchâtel, starting with the exploratory experiments, which were initially aimed at testing the interest and the relevance of the problem we had chosen, before going on with the experimentation in Microworld , where we can simulate the balance conditions of a tightrope walker figurine.

1. A first exploratory experiment with children aged 8 to 15

An initial exploratory research (May-June 2006), within which the case of the tightrope walker was studied, was carried out in the context of practical work in psychology with students who had attended, during the academic year 2005-2006, a course about the ways sciences can be taught. The observations were made with young children who were contacted by the students. The test was conducted with 10 dyads (age range: 10 to 20

years old). We insisted on the initial question: "*Why does the tightrope walker figurine keep its balance or why not?*"

The aim was to examine whether the problem led the young learners to identify the many variables that explain balance and whether the problem allows for confrontation of different points of view (due to distinct centrations or to different conceptual levels).

Observations

During the discussion, children gave numerous kinds of explanations. Here are a few examples :

- *The sticks allow balance (8 years)*
- *If there is a stick that's longer than the other, the man leans (8 years)*
- *Because it is the same weight (9-10 years)*
- *It must be the same on both sides (9-10 years)*
- *It cannot fall down on this side because it's drawn from the other side (9-10 years)*
- *The weight must hold the man, it must always be below the man (9-10 years)*
- *That must compose an axial symmetry, both sides must be exactly the same (10 years)*
- *It is because there is the same length on both sides (11 years)*
- *He keeps his balance when it is the longest stick (11 years)*
- *There is something below which supports it (11 years)*

These spontaneous explanations appear to be:

- more or less complex because of the relations the children referred to. Most of these explanations certainly refer to the equivalence of the elements on each side of the tightrope walker figurine. But when there is a weight that is heavier than the other, or a stick that is longer, the learners rarely take the multiplicative composition of these factors into account.
- more or less explicit in their formulation of the variables involved
- more or less connected to prior knowledge or experiments. The mobilisation of prior knowledge is, for example, explicit in the statement made by a 10-year-old child: «That must compose an axial symmetry, both sides must be exactly the same». But as we will see again later, the concepts of physical moment or centre of gravity, which are part of the program of science lessons in the secondary school, are rarely spontaneously mobilised in our situation.

Discussion

This first exploratory experiment showed that the problem we selected gives rise to interesting reactions and explanations from the children. Consequently, it seems to be a relevant material to use as part of the didactic approach of the ESCALATE project.

It also led us to examine a few questions about the way to guide the pupils' activity. Indeed, the dynamics of interaction and argumentation are linked to different pedagogical options:

- Shared material for the dyad, or each child gets its own?
- What question should be asked to start the activity with the pupils?

- When does the adult need to stop the action of construction in order to encourage reflection and discussion?
- What should be done with previous school knowledge that the pupils try to use?
- How should the activity be concluded? With an explicit statement? Or formal knowledge?

2 Second exploratory experiment with a few university students

This second experiment was set up following the observation that some of the psychology students who had questioned children during the former experiment had found it really difficult to figure out which factors govern the tightrope walker figurine's balance.

This led us to film two groups of first-year University students when confronted with this problem. The two dyads spent 30 and 50 minutes working on it. The two discussions were transcribed.

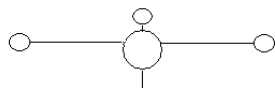
Observations

For these students, the mobilization of knowledge that had been acquired during former physics classes in high school is not easy, as shown in the following extract:

(B : the professor ; A1 and A2 : the two students)

B – « What are you doing? »

A1 – « I'm just trying to put the same weight and the same length on both sides. And then



see if that holds »

B – « Intuitively, would you say that it holds? »

A1 – « Intuitively I would say yes »

B – « Why ? Can you explain it to me ? »

A2 – « In my opinion it doesn't hold »

A1 – « So let's see »

B – « Then wait »

A1 – « Ah all right »

B – « We'll discuss first, because there's a disagreement »

A1 – « So in your opinion, will it fall there ? »

A2 – « I would say yes, that it will fall »

A1 – « Where will it fall ? What did we say ? »

A2 – « It will fall ahead or behind »

A1 – « Why? »

A2 – « Mmh, I don't know...in fact I don't know why. I've got the impression that an inclination on the side is necessary... or rather downwards »

A1 – « Why? »

A2 – « I don't know why »

A1 – « Yes... »

B – « And you, why are you saying that it'll hold ? »

A1 – « That's true, why am I saying that it'll hold ? It's muddling me. Why am I saying that it'll hold ?...The social representation, it's the tightrope walker, it's got two poles»

B – « It's an argument, then you can try to make it hold »

[The tightrope walker falls down]

A1 – « Oh no, that doesn't hold »

B – « Yes, but how can you explain that ? Because a human acrobat would keep his balance. What do we need to take into account ? Maybe this is something we can talk about »

A2 – « The angle. The angle must be tilted towards the bottom»

A1 – « Ah yes, it's interesting. Why ? »

A2 – « I don't know, it's as if... how can I say... »

When the students were invited to use concepts of physics such as the centre of gravity, they turned to them, but with difficulty:

B – « Are there some concepts that come to your mind ? »

A1 – « Yes of course, firstly, the centre of gravity »

B – « Could you explain it to me a bit ? »

A1 – « Yes, so, first we have the centre of gravity. By definition, the centre of gravity, it's the place on the object that, if someone puts his finger on it, it must keep its balance ».

A2 – « But here [when the tightrope walker figurine keeps its balance], where is the centre of gravity ? Is it in the middle ? »

A1 – « Yes, but if there wasn't this pole [the foot] and if you held it there [where the foot is], it would still keep its balance »

A2 – « So it's in the middle of its belly ? »

A1 – « Yes, it's in the south pole in fact »

A2 – « Say, on this line [vertical line which goes through the centre of the man] »

A1 – « Yes, I would say, in the south pole ».

Several times it appeared that for these students, the centre of gravity could not be conceived outside the material object. In this situation, the students were confronted with a complex object and not with a simple solid one (sphere or cube), as is usually the case when a teacher introduces the pupils to the concept of the centre of gravity. In this situation, the concept is not a non operational. Referring to the human body, these same students insisted several times on the fact that the centre of gravity is situated where the navel is.

The observations of students, who are older than the population first chosen (12-15-year-old children), proved to be extremely useful for understanding the dynamics of mobilisation of previous knowledge acquired during the science lessons or from everyday experience.

After learning much from the two exploratory experiments, we felt ready to leave the « laboratory » to test our scenario in a real classroom situation with a secondary degree class.

3 Experiment in a science class at the secondary school

In this part we present an experiment that was conducted in a secondary classroom, with the collaboration of a science teacher. We will first focus on the context of the experiment and then present the main observations of the principal steps of the scenario followed by the teacher with her students.

The context

The scenario was tested in a secondary degree class (13-14-year-old pupils) in La Chaux-de-Fonds. The experimentation was carried out during a chemistry course (2x 2 lessons). The teacher was found through personal contacts. She was interested in the project and who agreed to let her class be tested. As Lea Oswald, the collaborator who carried this experiment out, said: « This was carried out thanks to people I knew from my personal network. I first contacted a friend of mine, also a teacher, in December 2006. As he did not have enough time for the experiment, he proposed that I contact a friend of his, who teaches in the same secondary school. I met the teacher, Christelle Gertsch, in February 2007 and we decided on a date, in March 2007, to carry out the experiment ».

The experiment was carried out on the 27th and 30th of March 2007, during the time usually spent for chemistry courses. The class (20 pupils of 13 - 14 years old) was divided into two groups of 10 pupils and filmed.

The scenario that we presented to the teacher was accurately followed and besides, she made a few contributions. Firstly, she added a gap text that the pupils had to fill in at the end of the experiment, and secondly, she gave an explanatory and more theoretical card on the phenomenon of balance in order to end the lessons with a temporary conclusive synthesis.

Observations

First stage : Will it keep its balance or not ?

The teacher presents two tightrope walkers to the class (one which will keep its balance and one which will not) and asks the pupils to predict what will happen. The pupils do not all have the same opinion. Indeed, half of them think the figurine with short and horizontal arms will keep its balance, the other half thinks the figurine with long and vertical arms will keep its balance. Then, the teacher demonstrates the tests : it is the latter figurine that keeps its balance.

Second stage: construction of a tightrope walker figurine in small groups of 2 or 3 pupils

The pupils are invited to build tightrope walker figurines with the available materials (each child gets a tightrope walker figurine and many arms having different lengths).



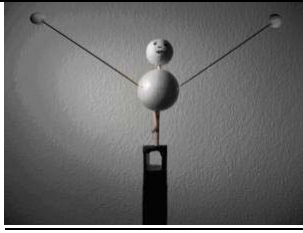
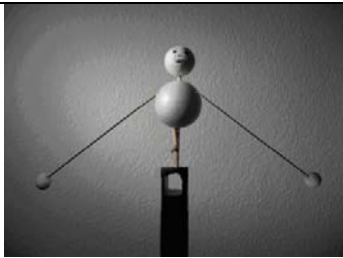
On the first attempt the pupils often manage to make a tightrope walker figurine keep its balance by imitating the figurine presented by the teacher during the first stage. The teacher encourages them to try new configurations (« there are several ways to ensure that it maintains its balance »). The pupils encounter many difficulties in describing what they are trying to achieve : they can identify a few factors, but it is hard to explain why these are important. There is not much discussion between the pupils (perhaps due to tiredness at the end of the week ?). Nevertheless, they try several configurations.

Third stage : Picture analysis

Each group receives pictures, and the pupils then have to determine whether the tightrope walker figurines can keep their balance or not. They talk together and then write down their arguments on a piece of paper.

Some pictures do not pose any problems, whereas others are the subject of disagreements among the pupils. Several arguments are then formulated and confronted. The pupils also have difficulty in combining the factors (weight, length, the angle etc.) with one another and explaining why some factors are important in some situations. In order to make the arguments proposed by the pupils more visible, the teacher writes them on the blackboard.

The following arguments were given by the students :

 <p><u>Photo 1</u></p>	<p>« the weight is not balanced and the sticks are not put the same way »</p> <p>« the weights are uneven and the figurine does not keep its balance »</p> <p>« No, the stick is longer and heavier on the right »</p>
 <p><u>Photo 2</u></p>	<p>« Yes, it keeps its balance because the weights are equal, are at the same place on each side and are directed downwards »</p> <p>« Yes, it keeps its balance because the weights are equal and situated at the same height »</p> <p>« Yes because the arms point downwards »</p>
 <p><u>Photo 3</u></p>	<p>« No because the arms point upwards and it is more difficult to find stability »</p> <p>« No, because the arms are pointing upwards and this makes it more difficult to find balance »</p> <p>« It is not balanced because there is no weight at the bottom »</p>
 <p><u>Photo 4</u></p>	<p>« It does not keep its balance because the weights are too light »</p> <p>« It is not balanced because the weight of the sticks are too light compared to the one of the body »</p> <p>« No, the sticks are too far from the foot and they are too high »</p>

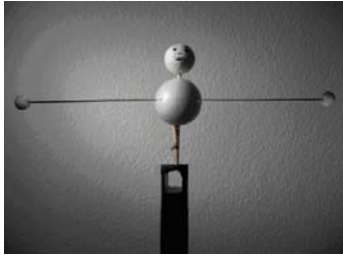
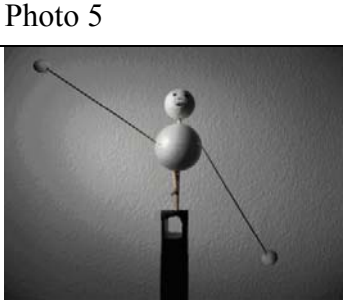
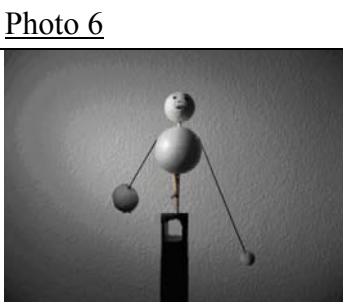
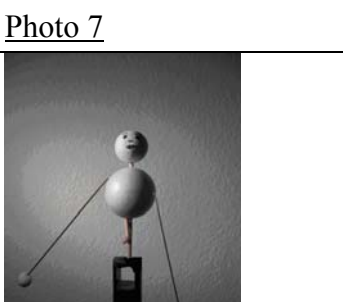
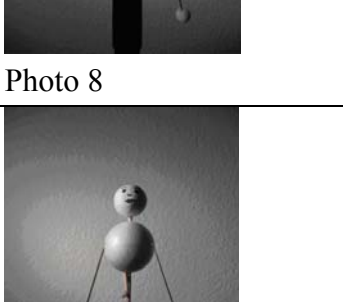
	<p>« No, because it's too long »</p> <p>« No, because the weights are in the middle of the body »</p> <p>« No, it doesn't keep its balance because the weights are in the middle of the body»</p> <p>« No, because the arms are too long and too heavy compared to the body »</p>
	<p>« I think it doesn't keep its balance because of the inclination of one arm downwards and of the other upwards»</p> <p>« I don't think so, because one arm points upwards and the other one downwards »</p>
	<p>« Yes, because the weight is equal, a bit larger and thinner on one side and a bit smaller and longer on the other »</p> <p>« No, because neither the weights are similar nor the lengths»</p> <p>« No, because they have neither the same weight nor the same length »</p>
	<p>« No, it is the same length, but not the same position »</p> <p>« No, there are the same weights but they are not positioned at the same place »</p> <p>« No, the weights are the same but they are not correctly distributed »</p>
	<p>« Yes, because there are big differences »</p> <p>« Yes, I think it keeps its balance because the weight isn't much different »</p> <p>« It is balanced, because the arms are close to the small wooden stick (the foot) »</p>

Photo 5

Photo 6

Photo 7

Photo 8

Photo 9

Fourth stage : True or false arguments

The pupils in groups receive a sheet containing a list of arguments. They must determine whether, in their opinion, they are true or false. The pupils try to reach agreement and to combine the different factors that play a role. But they always have some trouble explaining why and when the factors are important.

To make the tightrope walker figurine keep its balance, you have to...

	Right	Right and wrong	Wrong
... put sticks having the same length	10		8
... put short sticks	4		14
... bend the sticks so that they both form the same angle	9	4	5
... put weights on both extremities of the sticks	7	1	10
... put light weights			18
... bring the figurine to a standstill	14	1	3
... make sure that the man isn't too heavy	4		14
... make sure that the man's leg isn't too short	4		14

Then, the teacher examines each argument again in a collective discussion with the pupils.

Fifth stage : Introduction to the concept of centre of gravity

The teacher introduces the concept of centre of gravity and establishes a connection with what the pupils have noticed while building the tightrope walker figurine. The pupils are then invited to individually fill in a sheet noting the main factors involved in keeping the tightrope walker figurine's balance.

Then, the teacher gives a synthesis of what was discussed about balance by repeating the arguments previously formulated and written down on the blackboard. A new discussion is opened in order to bring clarification. Finally, the pupils are invited to evaluate the lesson and its structure.

4 Test of a Microworld

In this part, we will present the realisation of a Microworld designed to facilitate the systematic experimentation of the variables involved in keeping the tightrope walker figurine's balance. We will first describe the model that was initially designed with the modifications we made after a first experimentation with students.

The model of the tightrope walker

The model was designed using simple means. In fact, the tightrope walker was drawn with the turtle mode in a Logo system (Starlogo). A few parameters are adjustable with cursors, and others appear as variables that can be modified using the Logo code. The outline of the « man » (figure 1) is simply a segment and a circle on top. The pole (stick)

is composed of two joined segments that constitute a 90° angle (fracture angle). There are circles on both ends. A small dot represents the rope and another one the man's centre of gravity.

The parameters that can be adjusted with a cursor are :

- The orientation of the pole in relation to the body of the tightrope walker (abar)
- The length of the sticks (the lengths are the same) (ldb)
- The weights on the left and on the right (pdg, pdd)

The other parameters are (figure 2) :

- The man's weight (pdf)
- The man's height (long)
- The height of the pole centre (hbr)
- Fracture angle

There are two more boolean variables, one (shCG) which indicates if the gravity centre of the system is systematically indicated ; another (delOld) which allows or prevents the user from deleting the previous tightrope walker's position once the parameters have been changed.

Three buttons can be used to display the model on the screen :

- **setup** draws the tightrope walker taking the values of the variables into account. But this button keeps the tightrope walker in a vertical position.
- **movef** sets the tightrope walker in a balanced position (figure 2). In this model, we suppose that the man's feet are fastened to the cable.
- **myst** draws the gravity centre when it is not systematically displayed by the boolean variable as it is supposed to.

A fourth button should allow uninterrupted modification, but the operation is difficult to present in this drawing mode.

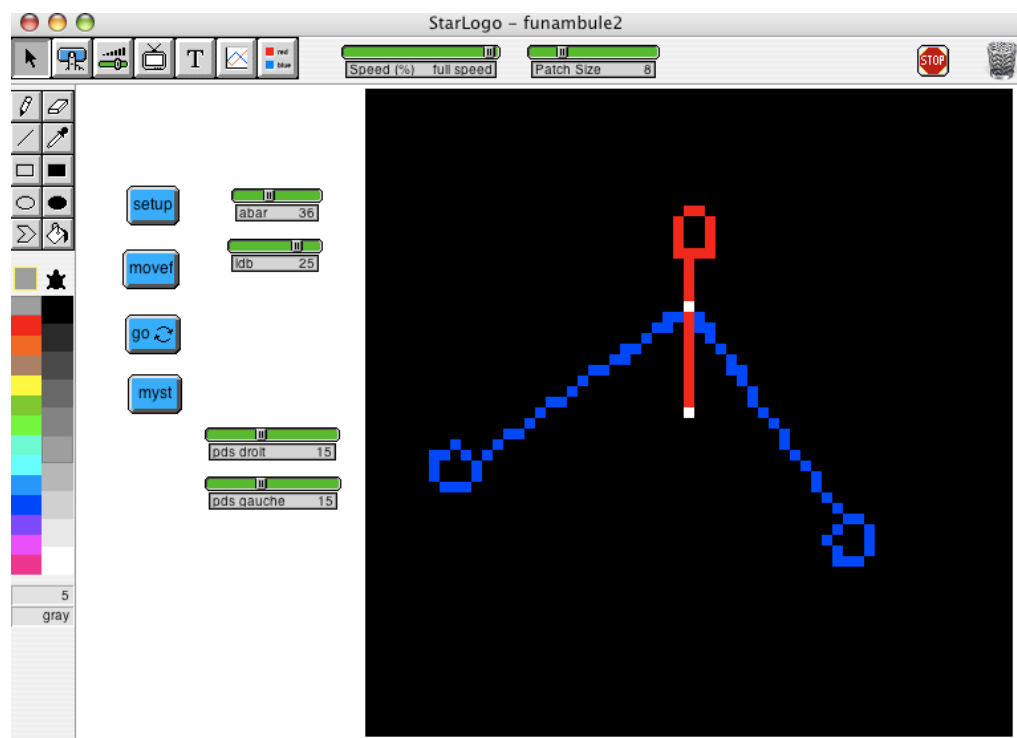


fig 1. The tightrope walker and his pole

Observations of the use of this model by two pairs of students (1st year University students in psychology and education), who had had the opportunity to study a «real» tightrope walker made of needles, corks and polystyrene balls, were made.

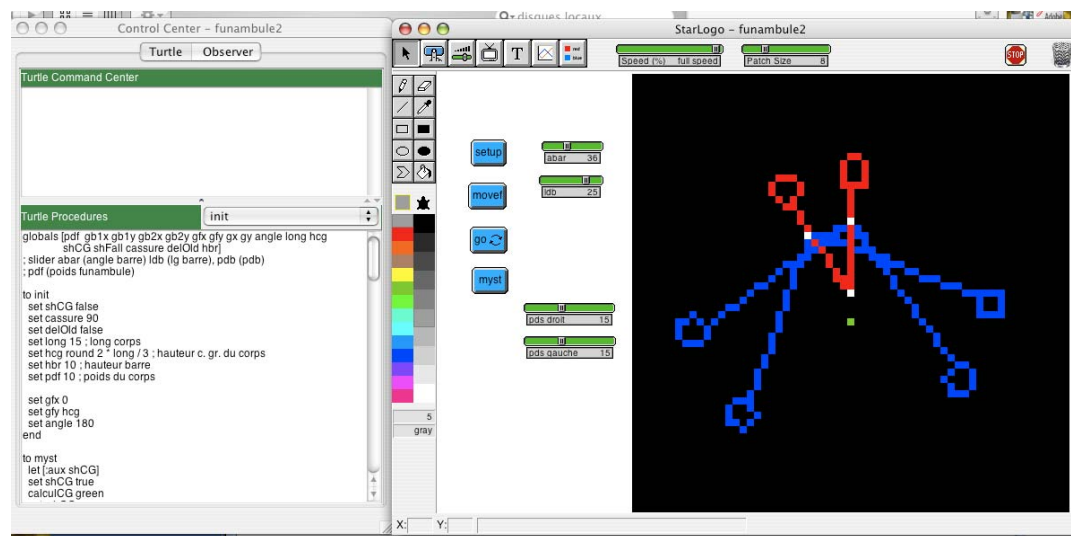


fig 2. The tightrope walker in a position of equilibrium

First observation

The two students are asked to explore the device.

The first critical remark is about the representation. Indeed, the students, influenced by the experimentation with a «real» tightrope walker figurine, encounter trouble in representing the phenomenon in two dimensions. Influenced by the dimension effect, they seem to see the tightrope walker leaning forward.

Suddenly, their requests refer to the access to a nonexistent variable in the form of a cursor: fracture angle (with the idea of placing the pole horizontally). They also refer to the possibility of varying the length of the two poles independently.

We noticed that the modification of the variables without the cursor is not very easy. Indeed, after each change, a compilation is necessary which hinders reflexion.

The students say they would appreciate if they could modify the position of the pole directly with the mouse. This idea of direct modification will be realised in the second model, while keeping the cursors which concretely represent the value of a parameter.

Another suggestion resulting from this first experimentation is the requirement to keep trace of the pictures and their parameters.

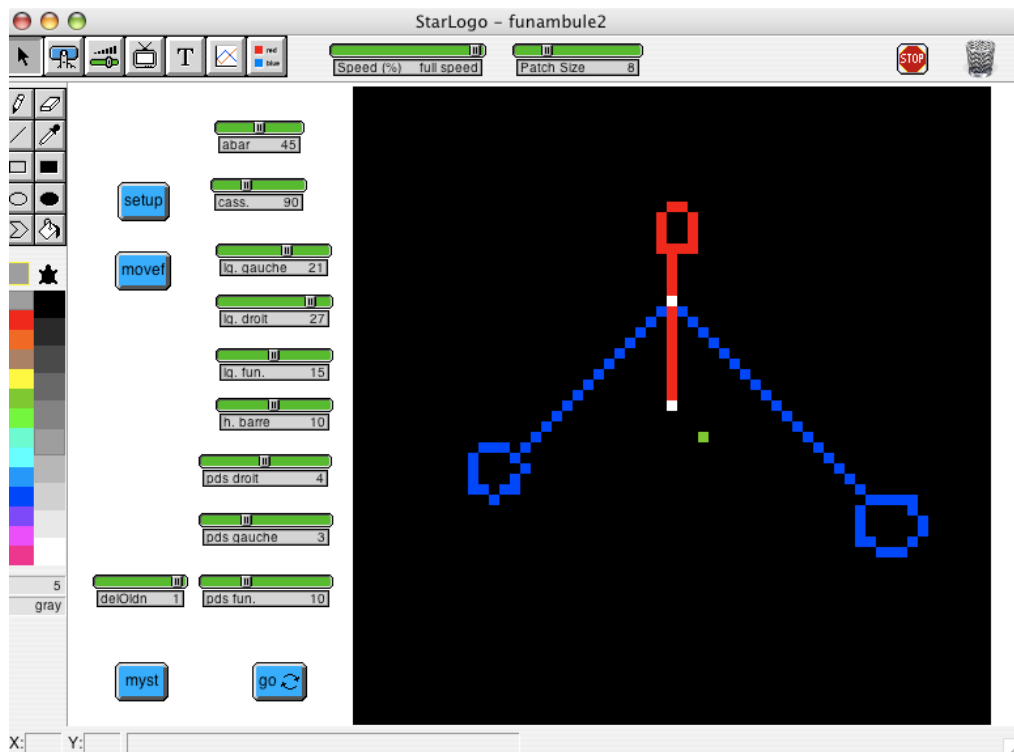


fig 3. Second version of the model

At the beginning, the predictions made by the students about the final position of the figure are erroneous. They think that if they tilt the left pole to the left, then the tightrope walker will tilt to the same side. The source of this misconception should be examined : is it the effect of the graphical representation or is it caused by the confusion due to a dynamic problem (like taking a run-up)?

The concept of centre of gravity was never used spontaneously during the experimentation. The students seemed to ignore it.

Second observation

Here, the Microworld was modified so that all the variables, including the possibility of adjusting the left and right poles independently, appear in the form of cursors (figures 3 and 4).

This time the two students (also 1st year University students) can handle the system directly. They first shyly attempt to explore the values of a few parameters.

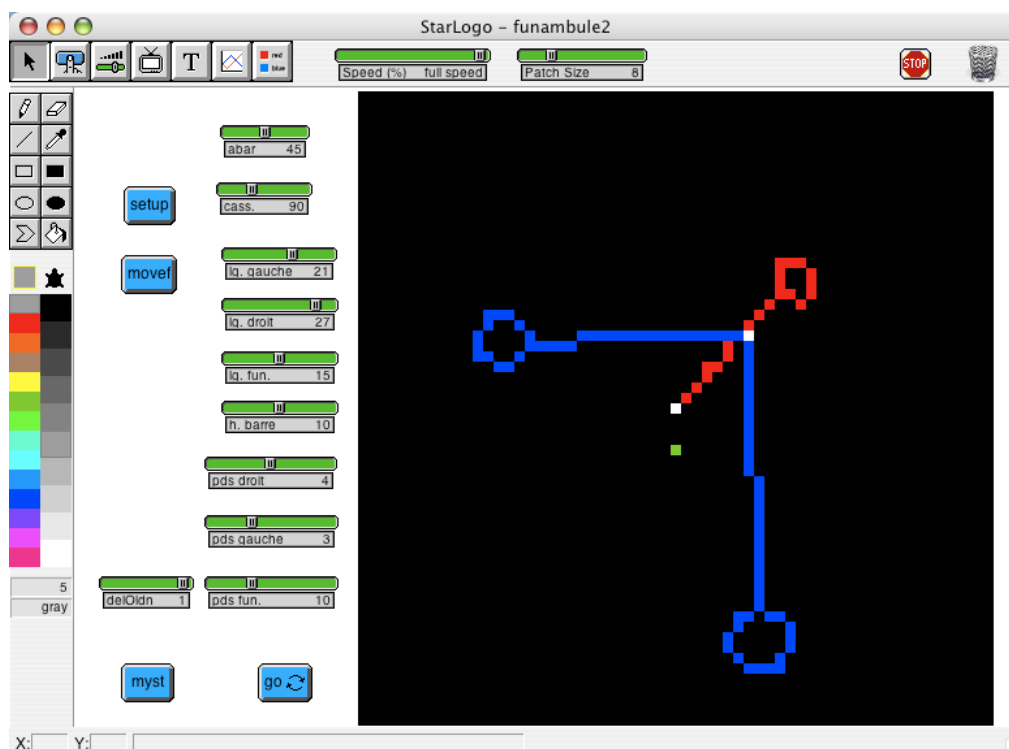


fig 4. In a position of equilibrium

The auxiliary hypothesis about attaching the man's feet to the rope gives rise to many discussions about the precise time when the man falls and referring to a physical model in order to check out that the man can lean without falling down.

The idea of centre of gravity is mentioned by the students, which gives us then the opportunity to show the students how to display it by operating a sequence which is becoming increasingly automatic: the modification of the parameters (setup, myst, movef, myst). However, the role of the centre of gravity seems to remain mysterious and the students have a difficult time in understanding it because it can be situated outside the object.

A relatively long discussion takes place about the problem around the exactitude, of the simulation, as, for example, when the centre of gravity is too close to the rope and it does not seem to pivot from the same angle as the rest of the device.

This Microworld and E-Slate

It was planned to include this Microworld version in E-slate, using the Logo and Turtle components of this system and taking advantage of the Spreadsheet components to record the successive parameters according to the suggestions of the first students. Thus, several simulations connected to the same project would have been made available in the same E-slate environment. However, this adaptation will not be available until a technical problem, which seems to occur with the Turtle component in the system version, has been solved.

Another improvement would consist of decreasing the degree of schematisation and of proposing a model more similar to the guiding principles by using a more sophisticated environment than a simple drawing. E-slate contains the « Stage » component, which makes it possible to handle shapes representing certain objects and to alter their features

(like speed, weight, etc.). However, the use of these agents remains a perplexing problem, and additional programming in « supervision » mode remains necessary. This point will be discussed further.

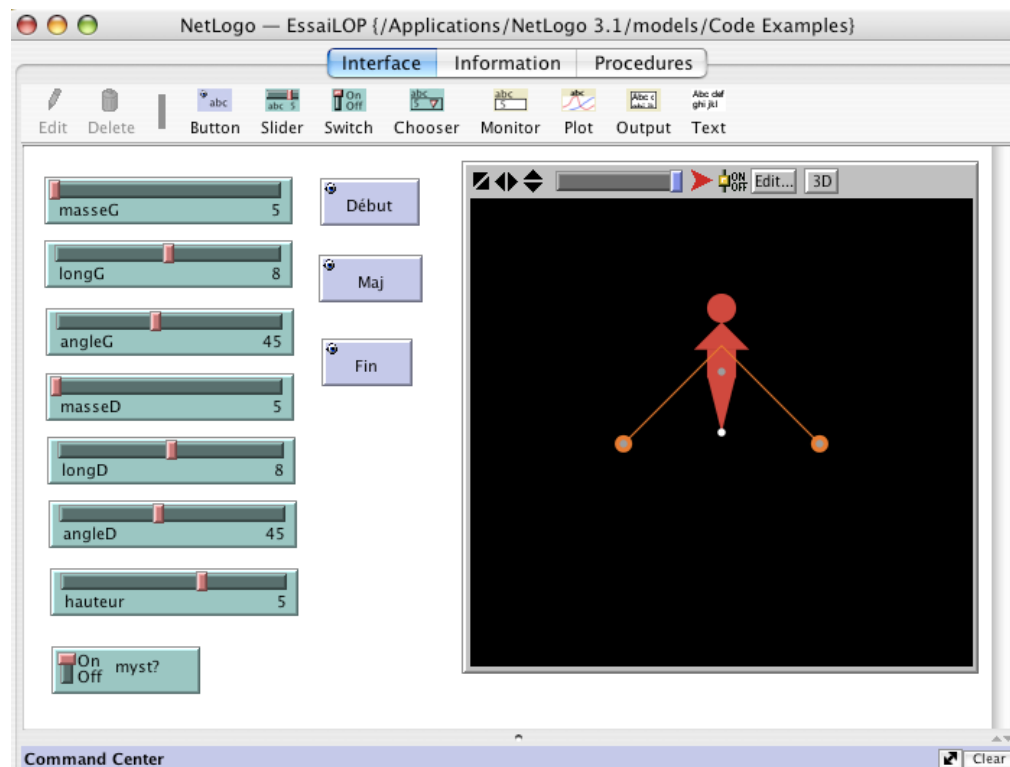


fig 5. After « Début » (= start): The tightrope walker appears with parameters by «default»

Unfortunately, it seems that E-slate does not yet allow the forms to be edited, which permits the multiplication of properties that are associated with them (for example, it does not seem possible to give an object the property to be swivelled). The new simulation was thus developed in the NetLogo environment. The model takes the two observations that were carried out into account.

The new representation appears in figure 5. It is composed of four objects (agents) : the man, the left and right parts of the pole¹² and the rope. The first three parts have a « centre¹³ », which is marked. As for the parameters of the pole (the fracture angle and its position compared to the man) which were not « natural », they were replaced by the angle formed between each pole and the man. The button « Début »(=start) displays the tightrope walker, the button « Maj » makes the representation conform with the parameters (in a vertical position) (figure 6) and « Fin » (=end) (renamed « Pos. Fin ») displays the tightrope walker in a position of equilibrium (figure 7). It can be noted that the use of the « switch » can both allow or disallow the display of the centre of gravity. Then a button was added, « Pos. Cont. », which allows the tightrope walker to progressively modify its position of equilibrium as the parameters are modified (figure 8). This partly corresponds to the first experimenters' requests.

¹² In fact, the pole is composed of two objects : the stick and the ball, which the program has to maintain bound together. With NetLogo there is the possibility that the user can bind objects, but this is still in the experimental stage and should be used later.

¹³ « Natural » centre of gravity, which corresponds, in an intuitive perception, to a geometric centre.

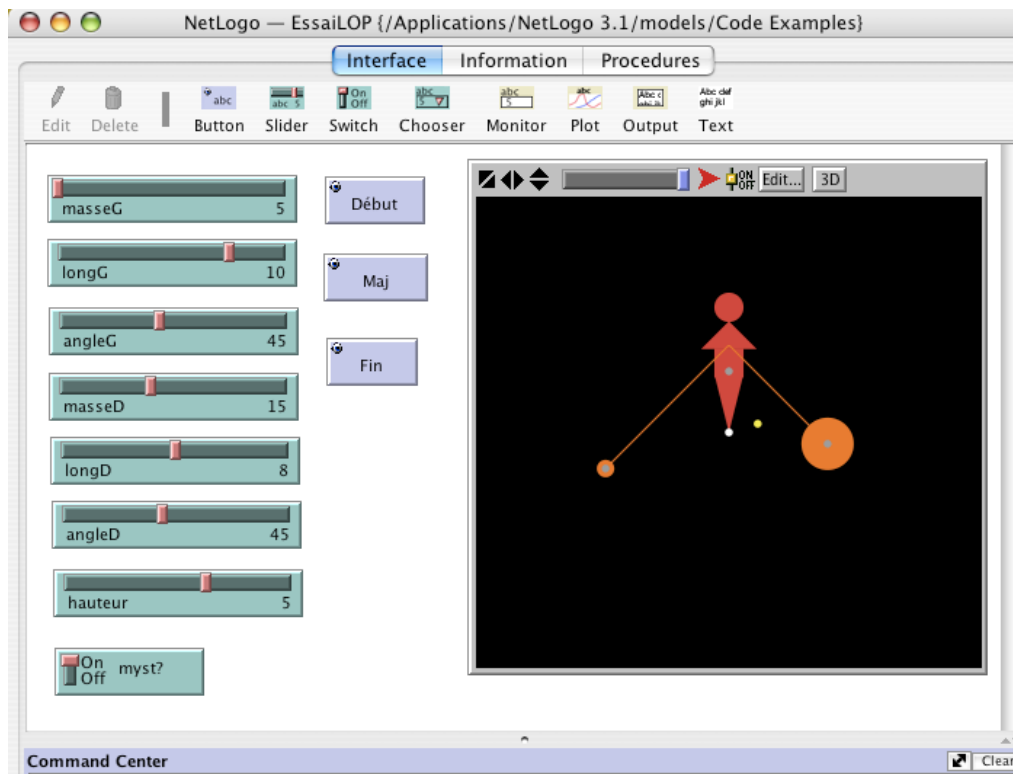


fig 6. After « Maj », the representation is modified according to the parameters.

The small environment of the tightrope walker allows examples to be given of the characteristics of a simulation. First of all, it is obvious that the system has its own time. Furthermore, the « time » factor is omitted if both buttons « Maj » and « Pos. Fin » are used. The degree of openness is typical of the systems based on Logo and mainly depends on its practical use and on the teacher's or learner's degree of language control.

The degree of schematization is low, the model is more analogical than structural, particularly in the second version, which allows the continuous rotation of the tightrope walker around its fixed point as the parameters are progressively modified.

Level of modeling: modeling is on an intermediate level. The tightrope walker's position depends on the centre of gravity of the system. A more primitive modeling (based on basic concepts) would only apply the centre of gravity and the laws of attraction to a simple object. A more sophisticated modeling would calculate the position of the tightrope walker directly, without using the centre of gravity which would emerge from the laws of attraction and equilibrium.

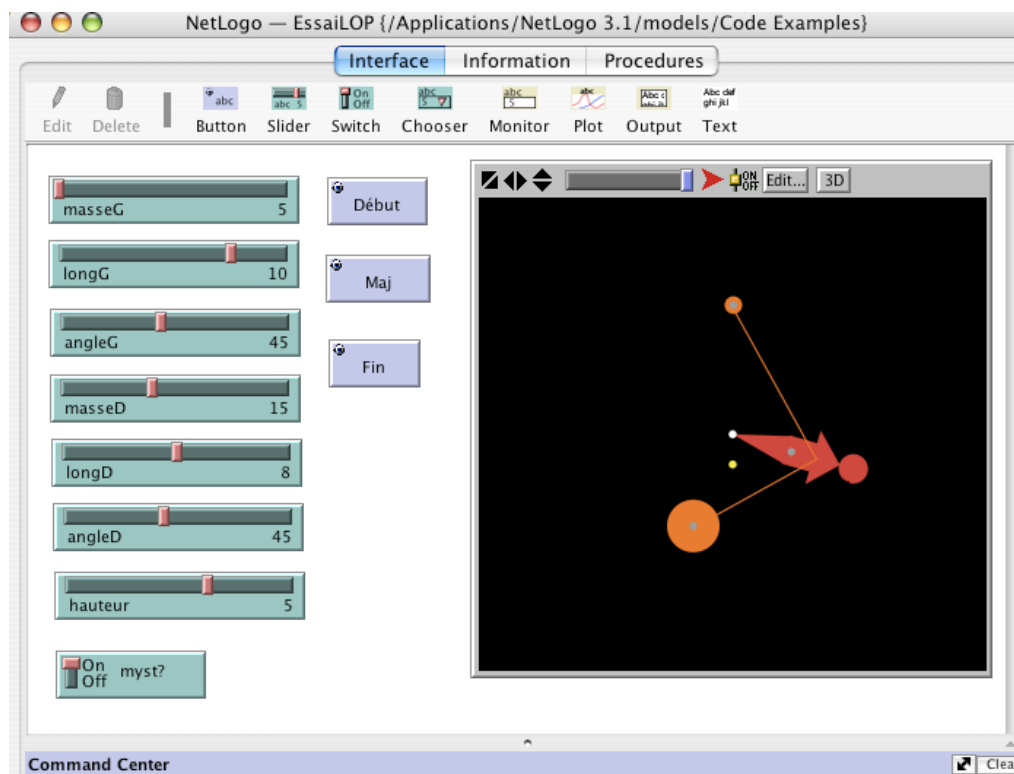


fig 7. After « Fin » (=end), the tightrope walker stands in a position of equilibrium.

In the first simulation, the programming is fully done in the supervision mode, there are no other agents besides the « turtle » ; the observer supervises everything. In the second case, other agents are included (some are mass bodies, others are centres of gravity to which the weights are linked ; others are objects whose characteristic is the measurement). However, the whole system is controlled by the external observer. The concept of the centre of gravity of a heterogeneous object is also introduced. The agents do not have many interactions (except when the sticks are lengthened, then the adjacent balls are moved away from each other¹⁴). A more basic modeling would introduce an additional agent, the earth, and the laws of attraction. In this case, the centre of gravity of a heterogeneous body would be indicated by the system.

Discussion

The new model still remains to be tested. If, as a generic task, the students have to explain (to predict) the position of the tightrope walker according to the parameters involved (to predict whether it will keep its balance on the rope or not), then it is possible to outline a prior analysis (from a didactic point of view) based on the two observations that were carried out.

First of all, the device will have to take into account the knowledge the experimenters have in physics (centre of gravity). Then it will be possible to distinguish three stages in the resolution of the task. The stages would correspond to three levels of knowledge the experimenters might have about physics (the centre of gravity is outside their ZPD, the centre of gravity is in their ZPD, a previous knowledge of the centre of gravity exists).

¹⁴ The NetLogo experimental device (3.1), which makes it possible to « **substantially** » define relations between the agents, is not used. It would, however, make the programming of the entire system easier ; for example, the rotation of an agent would cause the rotation of the whole.

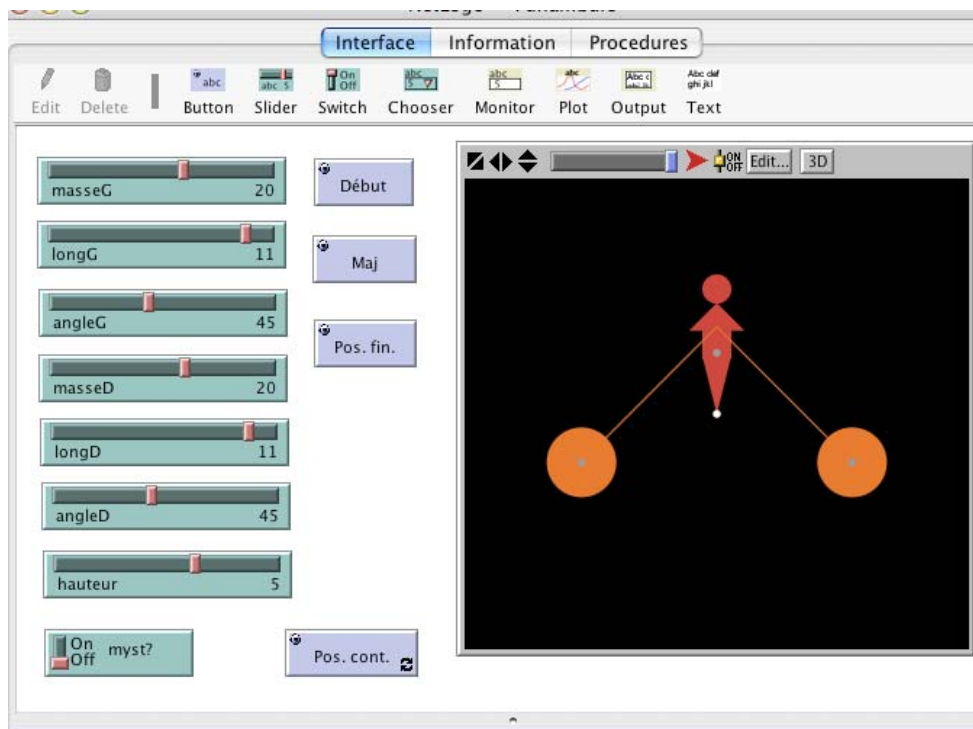


fig 8. With « Pos. Cont. », the tightrope walker changes its position of equilibrium as the parameters are modified

- 1) The first phase is planned for the students who do not understand what the centre of gravity is. The first group was almost in this situation. In this case, the tightrope walker should be replaced by simpler, monolithic objects. The predictions will first be about extreme cases. It is not unlikely that the centre of gravity will be perceived as a geometrical centre. Balance will be perceived as a result from the distribution of the forms rather than of the masses. Simple three-dimensional handling and constructions on a piece of paper should be added to this « construction » before starting the following stages.
- 2) Those students who have heard about the concept of centre of gravity (this is the case of the second group) should establish a link between the representation on screen and in reality, note that the model represents the case of the « real » tightrope walker very well, i.e., many « facets » (Tiberghien) of the model correspond to reality. The task would consist of « building » the centre of gravity of a composite system. We can suppose that if the experimenters alternate the « predictions » (that can be checked with the « Pos. Fin » button) with the simulations (« Pos. cont. »), they will manage to find an « abstract » centre of gravity (outside the body) which will help them to efficiently predict the position of the tightrope walker.
- 3) When the concept of centre of gravity is familiar to the students, it is probably more interesting for them to build a part of the simulation. The technical parts would be provided. The task would consist of finding the function which would calculate the position of the centre of gravity as well as the procedures necessary to find equilibrium. In the context of a real classroom, in order to justify spending time in learning the language, several activities should be planned in the same environment.

Part 2 : Experiments carried out at the Alta Scuola Pedagogica (Locarno)

We will present here a synthesis of the works carried out at the Alta Scuola Pedagogica of Locarno. This graduate school is in charge of teachers training in the canton of Tessin. The vice-director, Giorgio Häusermann, is strongly involved in the field of science teaching. He organizes diverse activities aimed at awakening interest and curiosity in sciences. He has collected an amazing set of toys which intrigue children. These toys were selected and gathered because they demonstrate various physical phenomena, such as force, energy, light, magnetism, floating and balance.

The question of equilibrium appeared to be the best topic to use for the group from Neuchâtel and the group from Locarno to collaborate on the ESCALATE project. We decided that the Alta Scuola Pedagogica would examine how the observations and discussions, around the toys especially designed to allow the children's awakening of scientific curiosity, can give rise to areas of investigation and argumentation, according to the objectives of ESCALATE, as well as to opportunities for formulating the acquired knowledge.

The case of the tightrope walker was thus integrated into a pedagogical approach, which is characterised by a broad approach to the topic of equilibrium.

During the school year 2006-2007, experimentation was carried out in a primary school in Locarno, in 4th grade. The experiment was the subject of a detailed report¹⁵. It was conducted during 5 lessons that were planned from September 2006 to April 2007.

First lesson : Body equilibrium

This first lesson aims at intriguing the pupils and at arousing their curiosity about the problem of balance: What does « balanced » mean? The pupils' interest relates to their own experiences. What happens when someone loses their balance? The aim of this first stage is to create a climate in which discussion and reflexion about the problem of equilibrium can take place.

Thus, the pupils are invited to walk on a straight line drawn on the ground. Do they manage to walk on the line with the arms against the body or with the arms spread wide ? While balancing a heavy bag in both hands ? blindfolded ? Or while wearing distorting glasses? After carrying out these practical and perceptive experiments, the pupils are invited to formulate hypotheses : What facilitates the state of equilibrium ? What makes it difficult in each situation that was tested?

The discussion allows the children to identify the main factors which play a role in each situation that was tested (such as concentration, the arms being spread wide, the case of looking straight ahead or looking down). The lesson goes on with the presentation of several toys which show various balancing acts (the loose rope ; the tightrope walker; a ball with a suction pad that adheres to the window pane; three ropes tied to a ring on which it is pulled in three directions; spinning tops).

¹⁵ <http://did-asp.ti-edu.ch/~giorgioh/liv2/rapportoaprileescalatehtm.htm>

The pupils write down their observations and explanations. Almost every child writes something different. An object's balance is often considered a static phenomenon, without taking the role of the movement into account (as, for example, in the case of the spinning top or the bicycle). During the week, the pupils are invited to continue their exploration and observation inspired by these various toys.

Second lesson : the toys in positions of equilibrium

New situations of balance are presented to the pupils. The first one shows magnets attracting the pages of a diary up in the air. Two tightrope walker figurines cycle on a rope without losing their balance (one man is holding two counterweights, the other one is holding only one counterweight at the centre). Then the pupils discover two more toys in balance: a bird standing on its beak and an elephant.



When explaining how the bird keeps its balance, some of the pupils, on the one hand, mention the role that the weight of each wing plays. Some pupils, on the other hand, first formulate the hypothesis that it is the pointed beak of the bird that allows it to keep its balance.

Third lesson : building up a bird in a position of equilibrium

The aim of this lesson is to model a bird in a balanced position from simple materials. What shape does it require ? When does it keep its balance and when does it not?

At the beginning, the children find the task a little difficult. Indeed, they do not know how to start. But two pupils found a solution, and this was enough to motivate the others to continue their research and tests. The children have trouble cutting the wire because it is thick metal. But in the end, almost all the pupils (except one) succeed in making the bird maintain its balance on the tip of its beak. They also managed to colour the bird the way they preferred it.



During the discussion that takes place after this phase of construction, it appears that the activity was an opportunity for the children to reflect on the distribution of the weight of

their bird and the arrangement of the wings (which must be placed beyond the head) in order to obtain a position of balance.

Fourth lesson : tests of knowledge and construction of the tightrope walker figurine

This lesson takes place more than three months after the previous lessons. It is a good opportunity to check what the pupils have learned from the previous activities. They are thus asked a series of questions on the following topics :

- directions and perceptions which play a role in the balance of the body;
- a list of true or false arguments that keep the tightrope walker's balance ;
- analysis of drawings representing tightrope walkers : can they keep their balance or not ?
- the position of balance or imbalance of a mathematical balance according to the distribution of the weights.

After these four tests, which serve as a revision of the observations that were conducted during the previous lessons, the pupils are invited to break into small groups and build a tightrope walker. The objective is to observe how the children reinvest, in a concrete task, the knowledge acquired during the previous experiments.

In this construction task, the pupils are really enthusiastic and are fully involved in the search for solutions. At the beginning, the construction caused a few practical problems. Indeed, it was difficult to put the available materials together, but finally, all the pupils managed to build a balanced tightrope walker. This phase of construction gave rise to relevant discussions within the groups.

Fifth lesson : balance and floating

The objective of the last lesson is to explore another aspect of balance, that is, immersion of various solids in a liquid. Why do some objects float, why do some others sink to the bottom of the container, and why do others remain between these two states (neither floating nor sinking) ?. The first topic of this lesson is about the floating body, which leads several pupils to the subject of the role that air plays in the lungs.

As for the various objects that are successively immersed in liquid, the pupils refer to the weight of the objects to explain why they are floating. This activity allows the children to discover the concept of density. Indeed, the pupils are encouraged to pay attention to the weight of an object in relation to an equivalent volume of liquid.

CONCLUSIONS ON THE TIGHROPE AND EQUILIBRIUM EXPERIMENTS

We chose a relatively complex topic about physical equilibrium with the intent of simultaneously promoting an activity of experimentation and an activity of reflexion and argumentation. Are these activities relevant from a pedagogical point of view, are they a source of new understanding ? After conducting experiments in several contexts, we can summarize the main observations:

The construction and the observation of a tightrope walker figurine is a didactic activity which, beyond all expectations, appears to be relevant at various ages (we have tried with experimenters aged 8 to 20!). The youngest children confronted with this task attempted

to identify the factors involved, using their intuition and their own experiments on balance. For the oldest, the problem was different. Indeed, for them, it was an opportunity to use, not without trouble, the knowledge acquired during previous science lessons in order to elaborate a model (an explanation) of the situation of equilibrium.

The first simulation tests carried out with the computer proved to be extremely interesting in the process modifying the times and durations of action and Microworlds on reflexion. It takes some time to become familiar with the software. This seems to slow down, at least at the beginning, the activity. Experiments need to be continued in order to determine when the computer-mediated activity becomes profitable in comparison with the hands on activity, in particular because it could allow the users to quickly change the parameters and to observe the effects.

To exploit these didactical scenarios, the time necessary for handling, reflecting and discussing the observations with the pupils should not be underestimated. For instance, the time necessary to explore and then control the Microworld, in order to use it efficiently, was underestimated. A 45-minute sequence is obviously too short. The Microworld requires some time before it becomes familiar and thus profitable.

Two didactic strategies appear have been explored: the first consists in asking the pupils to comment on a list of true or false arguments about equilibrate; the second consists in asking them to tell whether tightrope walkers drawn on pieces of paper would be likely to keep their balance. In some situations there is a general agreement, and all the pupils share the same opinion. But in other cases, their opinions are different and their answers are sometimes contradictory. The use of Digalo and its argumentative maps could be useful here to structure the discussion.

8.4 Case D: Marbles Move

Alaric Kohler

1. Introduction

This part of the chapter describes the implementation of the Marbles move case in a secondary school in Switzerland. Implementing an innovative pedagogical practice is known as a complex process with which any aspect of the context is likely to interact (Garduño, 1998). As the project's framework (timelines, objectives ...) can considerably shape the implementation analysed here, the case design and the researcher's activities are included in the following description of the research. In this manner, we hope to offer the reader a situated view on this case implementation within the ESCALATE project. We address our special thanks to Ph. Drompt for the invitation in his classroom and to F. Boubbadi for his active participation in the research process.

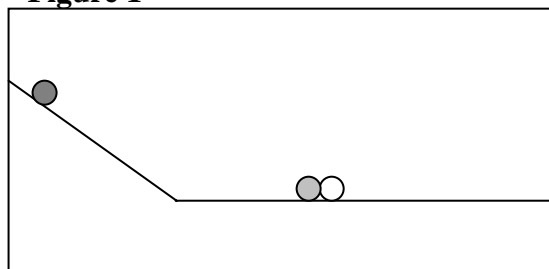
2. Case design

Task

First, the task chosen has to be appropriate for an inquiry and argumentation based pedagogical approach, for making a Microworld, and for the target age group's curriculum in science. The *Marbles move* situation has been elaborated from a task created by Piaget to test children's conceptions on movement and causality.

The central phenomenon looks simple (cf. figure 1): one marble on a slope rolls down on a rail till it hits one or more marbles on a horizontal surface. After the first impression of simplicity, this situation opens many complex issues of physics.

Figure 1



Considering the task suitability for an argumentative discussion in physics, we considered two criteria:

- 1) Does the task leave free space for personal interpretation?
- 2) Do students, whatever their formal knowledge in mechanics, have different points of view when considering the situation?

The *Marbles move* situation fulfils these two conditions: one can see a marble moving after the collision, whenever another one thinks it stays immobile. The scientific concepts of dynamics underlying the phenomenon are known for bringing up different preconceptions (Viennot, 1979).

Considering the task suitability for creating a Microworld useful for learning, we considered two more conditions:

- 1) Is it in the available technology range of Microworlds to make a high quality product with this task?
- 2) Does it offer relevant possibilities of activity for learners?

To answer the first question, the researcher based his judgment on his own knowledge and understanding of the technological requirements of E-Slate platform. Concerning the second point, we hoped that manipulating variables and observing their effects on the marbles dynamics faster and differently than with concrete material would support

inquiry learning and/or feed argumentation. Learning objectives were not set precisely at the moment of choosing a task, so as to avoid difficulties while implementing the task in a school curriculum.

Microworld

The Microworld is the first product of design, due to the project calendar. Indeed, ESCALATE technical partners programming the Microworld needed precise information at the very beginning of the project, which required more effort than just choosing and describing a task. Starting with technological partners presenting half-baked Microworlds in the first project meeting, the researcher designed the Microworld graphics and structure. The idea was to reproduce the tasks in a virtual environment in such a way that students could actively engage in a free exploration of the marbles' movements. This exploration is fostered by displaying a large set of variables that play a role in the marbles' movement and collision, giving the user an adjustable slider for setting each variable value, and displaying each marble velocity in real time (the marbles' positions were added later). The researcher met a physicist in contact with the Institute of Neuchâtel, and asked him to construct an equation underlining the visual simulation of the marbles' movements in the Microworld. This equation had to fulfil several constraints: it needed to be simple enough to be processed by the program language used to build the Microworld (to avoid efficiency problems such as delays or jumps in the displayed movements), to include all variables open to students' inquiry, set by the researcher, to visually simulate the event in the best way possible, and to correspond to the knowledge to be taught. The physicist offered the researcher a relevant and rich mathematical equation to manage the movement of the marbles in a one dimensional trajectory (see the Case template for details), including the effect of each marble mass, ground friction with two factors (dynamic and static), gravity, the marbles' height on the slope, and the marbles' positions on the trajectory.

While this equation did not correspond to standard textbook content, it was based on the requirements of variable definitions that were needed for programming the Microworld. These definitions were used in an equation dealing with the collision simulation, which needed to mathematically account for the interdependence of all variables included in the Microworld. The whole program was based on the velocity of each marble, as this produces the Microworld visual effect when playing the simulation. Using this approach, the researcher needed the physicist to find an equation describing the collision between two marbles, as the determination of each marble's new velocity according to all relevant variables involved in the collision. Above the usual necessary simplification needed in programming work, e. g., choosing which factors to take into account and which ones to ignore (for example, we totally ignored the effect of the marbles rotational movement), there was another limit to the physicist's work: it was framed by the computer program possibilities, only known by the programmer himself.

At the researcher's request, the technical team made some changes to adapt the first versions of the Microworld to pedagogical usability. As these changes were not modifying the global programming approach or the work already done, they were easily and successfully integrated into the Microworld. For example, some sliders' minimal and maximal values were changed to reach a more interesting visual effect, and a feature displaying each marble's velocity was added. In addition, the marbles' numbers were removed while the marbles are moving, because they were turning and therefore misleading the observer and because the equation was treating the marbles as physical

dots slipping and not as balls rolling. The end result of this design process is of a high quality for teachers and educators in terms of possible activities and complexity of the physics model, and for students, in terms of useability and affordances. In addition, the implementation proved the stability of the interface that resisted all kinds of unpredictable manipulations very well.

Pilot case studies

Once the collaborating school was known, it was possible to create the specific scenario with all the details fitting the initial idea of an argumentative and inquiry-based pedagogy, making the best use of ICT tools, and adapting the case to the teacher and/or to the school curriculum constraints. In order to fill in the worksheet and organise a long implementation in the classroom, the researcher carried out some exploratory work with the Microworld. This explorative work consisted of:

1) An activity with, and driven by students at Neuchâtel University: it was aimed at observing how young adults in teacher training programs can use the *Marbles move* situation as a pedagogical activity, and which insights or memories in physics naturally emerge from working on this task. Students were asked to design a scenario able to stimulate discussion, notably with the use of Digalo.

2) An intervention with the Microworld at the secondary school (the implementation school) in order to give the researcher primary feedback from the chosen sample of students: for instance, how did they react to the Microworld and how did they manage to use it in small groups? During this intervention, the researcher interviewed students in groups of three in a separate room, in parallel to the last lesson of the school year. The students had to individually answer a questionnaire with questions about the marbles' movements before and after the collision, and to discuss their answers in the group. Then, they were presented with the Microworld with very open instructions, asking them to "explain the phenomenon as best as possible".

3) An exploratory study was conducted with younger children working with the Microworld on simple tasks. Children's activities were video recorded in different conditions, for example, working individually or in pairs. These data allowed us to grasp some early conceptions induced or stimulated by the Microworld.

All these activities helped the researcher to design the sequence and in particular the worksheet accompanying the Microworld activity. The *Marbles move* situation turned out to be very rich in opportunities to study numerous mechanical topics, among which the designer had to choose some to focus on. It provided as well the main ideas and representations about intuitive resources of the students facing this situation. It happened to be quite problematic to reach a conceptual language, even for those having studied theoretical physics before. Digalo maps and recorded conversations analyses were particularly useful in choosing central physics issues for the case. Indeed, the free discussions carried out by the students showed that without any guidelines concerning the content of knowledge or the concepts to study, a lot of different considerations were formulated that cannot be jointly and constructively articulated by the novices. Without a precise pedagogical objective, the activity became too complex and quite discouraging for the learners. This first experience grounded the co-elaboration of pedagogical objectives and the sequence planning with the teacher, responsible for respecting curriculum and other school constraints.

Worksheet

The main activity of the sequence was built to integrate the Microworld and improve argumentation among students. For this activity, the researcher wrote a worksheet for 2-3 practical work lessons, with the assistance of a physics didactics specialist to formulate the instructions addressed to the students. This worksheet was conceived as a guideline for students to carry on an active exploration of the *Marbles move* situation. It follows Papert's (1981) idea of grounding the exploration of Newton's law on students' existing conceptions of the physical world. Students were provided with a worksheet, the digital tool Microworld, in addition to a hands-on experimental system made of a plastic rail with a flexible slope at one extremity, and two different marble sets, one made of wood, another of glass. This dual experimental setting was aimed at fostering students' reflexive comparison between the difficult observation of reality and the easier access through the computer, displaying a simplified model of the phenomenon.

The objectives of this worksheet were to gradually introduce the concept of Force, following Newton's three laws of motion. In an analogous way to Papert in his proposal to use dynaturtles firstly defined with velocity, secondly with acceleration and finally through interaction with other turtles, we chose to structure the worksheet in three parts:

- 1) Students were asked to describe the movement using marble velocity as a criterion to identify three different phases (one with an increasing velocity, one with a decreasing velocity in the same direction, and finally one with a velocity equal to zero).
- 2) Students were asked to describe the acceleration of the marbles in each phase.
- 3) Students were asked to identify when acceleration is not constant, and then to explain why this change occurs; the pedagogical objective of this consideration was to introduce students to their first contact with interaction between particles: friction as the interaction between the ground and the marble, and finally the collision as an interaction between two marbles, which illustrates Newton's third law.

At different stages of these activities, students had to identify variables playing a role in the phenomenon, and try to find out how they are related to each other. When answering on the worksheet, they had to express their descriptions in physics quantities both verbally (i.e., "velocity increase") and symbolically, drawing vectors characterising velocity (direction, sense and strength), acceleration, and force. The final point of this work consisted in drawing all forces applied to the marbles at each phase and during the two -marble collision.

This approach is based on two main choices: first, to focus on qualitative physics, with the hypothesis that this approach is more likely to change the students' misleading preconceptions; second, to leave the learners in front of the phenomenon without disturbing their thinking and observations because of a strong will to guide them towards a formalized knowledge (as a formula). The aim of the activity is to let the students develop a method of systematic observation with the help of the Microworld. We were expecting students to draw meaningful links between variables, and to relate concepts themselves, through their own active handling of variables and symbolic descriptions.

Design as an iterative process

The school organisational setting with practical work lessons every two weeks encouraged an iterative process. Having half the students one week and the other half the next week gave the teacher and the researcher the possibility to construct a representation of students' difficulties with the tasks and knowledge. Indeed, the teacher and the researcher noticed when an instruction was difficult to understand, or an introduction was missing, and adapted the planned scenario to improve this particular point for the next half of the classroom. A specific time after each lesson was dedicated to this exchange between the teacher and the researcher. However, this process was used only for details of the worksheet or for the teacher's introduction to the activities, probably because having very visible effects on students' activities.

3. School context

The school

The French High School of Bienne is situated in a relatively small city (fifty thousand inhabitants, ninety thousand with neighbouring agglomerations) with a traditional bilingual culture (55% Swiss German, 28% French speaking) and a more recent, but nevertheless important, cultural minority from Mediterranean countries (12% including Italy, Spain and ex-Yugoslavian countries). The high school also has a large proportion of students from the well populated surrounding countryside, as it is the only high school for French speaking young people in the area. Socio-economical level is rather low, as the city is developed mostly around the watch industry.

The objectives of this school aim at providing all students general knowledge to prepare them for university. The students have to follow physics lessons, but some have more intense scientific or mathematical teaching, depending on the option they have chosen in the curriculum. In our case, physics lessons are composed of theoretical lessons during which traditional teaching is provided by teachers one period a week, and by "practical work" lessons taking place every two weeks for two periods (one hour and a half each). Practical work lessons are an old tradition in this school; for these lessons the classroom is split into two halves (12 students in our case), offering the teacher a better possibility to lead group and experimental work. These lessons take place in a laboratory, well equipped with computers (5 laptops, including one for the teacher, connected by a local net), plugs, and other useful material. The usual activity carried out in these lessons consists in conducting a scientific experiment on a phenomenon or material setting. The experiment is then reported by the group in a paper which must follow a certain template, includes graphics or tables, and is used by teachers to teach the scientific method of using data to justify claims or answers, in addition to more traditional calculations.

Participants

The students (grade 11) were in their second year of high school and physics teaching, and were introduced to the experimental method. The previous year they studied the entire kinematics chapter. As for previous knowledge, it is particularly relevant to mention a lesson on vectors in mathematics they received before working on the Case. Their elected specific options were first "Philosophy, psychology and pedagogy", and for a minority of students "English". They were all familiar with ICT tools, for example, "msn messenger" was very popular in the classroom. The mere term of argumentation was not totally new in physics for them, as they spent one year having to write reports about laboratory work in which the teacher put an emphasis on the argumentative use of

data to support the experimental results. However, the students could not be considered as familiar with argumentation, because despite the teacher's efforts to make them articulate facts as supporting either one theory or another in the experimental reports, they were generally unsuccessful at putting results in an argumentative structure.

The teacher who accepted work on the project was a teacher in training, a young teacher having a part-time teaching position during his training at Teacher training college (Haute Ecole Pédagogique, HEP). At this stage of his studies, a teacher in training is supervised by an older colleague for his teaching (called here a "supervisor"), and by a teacher trainer from HEP for his masters thesis. The teacher in training could use the ESCALATE activities as a frame within which he could write his master thesis on an interesting teaching activity, and show how he benefited from the large amount of time he invested in the collaborative work with the researcher. In addition, he was very interested in the pedagogical approach of the ESCALATE project. Both the teacher and his supervisor were familiar with constructivist pedagogy, and the experimental approach to teaching science has a long tradition in this school. The supervising teacher had tried many approaches, following the educational trends of the last 30 years, and was therefore less interested in the ESCALATE as a resource for renewing practice. Nevertheless, he welcomed the project very positively, as he had been using an inquiry based approach and trying to foster students' argumentative reasoning in his practice for years.

Setting the collaboration

Just after finishing the Microworld design, we started to search for an interested school for implementation, which included succeeding in motivating teachers to participate in this specific task within the ESCALATE approach. It demanded from the researcher a clear discourse about the case possibilities for learning on one hand, and a lot of flexibility on the other hand, to be prepared to adapt to the local context of school and teachers' practices. The researcher first contacted his previous physics teacher. Access to a classroom does not benefit from an institutional structure in Switzerland, as teachers do not get any scheduled time or funding for carrying out activities with researchers. Nevertheless, thanks to the researcher contact, a meeting took place at school, where the researcher presented the ESCALATE project to the three physics teachers in place. The headmaster was informed of the researcher's presence, and participated in the second meeting to welcome him. He gave strong encouragement for this kind of initiative, as he acknowledged the importance and necessity of improving science teaching.

All teachers sounded interested in the project approach using argumentation and inquiry, but they were slightly sceptical with regard to the objectives of enhancing scientific teaching or science attractiveness. They had tried a lot of new pedagogical methods already, and were unsure of the outcomes. In addition, they made it clear that in their work context they could not invest much time in participating. To start with, the teachers invited the researcher to attend some of their lessons using experimentation. Then, the researcher could interview students during the last course before summer holidays. At the start of the new school year, a second meeting took place where the researcher tried to find with the teachers a concrete activity for starting collaboration. Although several possibilities to observe the running activities were offered to the researcher by the teachers, none of the ordinary teachers seemed to have time or enough interest to give any lessons for the ESCALATE implementation. The teachers either had their own way of teaching the concepts involved, or it was not their topic for the year. However, a new teacher in training attending this meeting and working as a teacher in training was very

interested in starting a long term collaboration. Since then, the researcher has only worked with this teacher in training and his classroom, under supervision. The sequence was mainly prepared at this point of the project, a few weeks before the implementation started. It had also been partially designed during the activity as an adaptation to the context of doing or as emerging thinking in interaction.

The collaboration between the researcher and the teacher in training was very open and informal, meaning they could discuss the students' activities design step by step and carry out these activities as they wished without having to report to anybody about it. It is certainly the positive counterpart of not having institutional management of the researcher's access to the classroom. The school context is further described below.

4. Implementation

Sequence

Before starting practical work lessons, the teacher distributed a questionnaire containing 6 items to the students, in order to grasp their preconceptions of different problems in mechanics and for initiating the plot of the sequence. Indeed, students did not receive any answers from the teacher on these 6 problems during the whole sequence, so that they kept them in mind as questions to ask.

Except for some minor changes to the worksheet, the scenario took place as intended by the designers. It lasted longer than expected, because several lessons were dropped from the schedule for extracurricular reasons. All in all, the classroom worked on the *Marbles move* from September to February, with the exception of one or two lessons which addressed related topics.

The scenario took place through the following steps:

1. A questionnaire about preconception, filled out individually without feedback or teaching.
2. Two or three sessions with the Microworld and materials, according to the worksheet activities carried out in small groups, and finalized with a conclusive discussion.
3. An argumentative activity in groups to share and discuss the questionnaire answers on Digalo, through a synchronous session.
4. An experimental activity in groups on the six situations of the questionnaire with real material, leading to an experimental report for each group.
5. Another questionnaire about the same preconceptions filled out individually as an indicator of change.

More precise information, including the worksheets, can be found with the Case description.

After the activity with the Microworld, students' attention was brought back to the questionnaire problems in order to initiate argumentative discussion about them. The teacher planned a Digalo activity for two practical work lessons, where groups of students had to build a classroom shared argumentative map in a maximum of ten minutes per problem. Students were set in the usual small groups, all together in the classroom, with one computer per group. All four computers were linked through a synchronous connection, allowing them to work in real time on the same Digalo map. In the map

settings, one layer was assigned to each question, so that students did not need to change maps to move to the next question, and could freely navigate from one question to another if they needed to. The objective of this activity was to set a two level discussion on preconceptions activated through the questionnaire: first, at the group level, students had to come to an agreement or at least a compromise on one answer for the group on the map; second, at the classroom level, each group's answers were confronted with the others' through the Digalo map. These two levels were supposed to interact with each other, for instance, if a group was contradicted by another one on the argumentative map it could raise doubt within the group and start the discussion again about the right answer to choose within the group. No final answers were given at the end of the activity, because the aim was to set a frame for students to engage in argumentative activity and to justify their answers. If the teacher was assessing or evaluating students' answers, it could stop their commitment into argumentative dialogue as the activity would lose its meaning.

For the last two lessons of the sequence, the teacher planned an experimental activity on the same 6 problems, with a specific material device for each of them. The teacher's objective for this inquiry-based activity was for students to find out the right answer following a scientific and experimental procedure. The researcher had a different objective, which was to compare which knowledge and explanations would emerge from this activity in comparison to argumentative discussion. After the sequence, students filled in again the 6 item questionnaire with slightly modified problems on the same physics questions. They also had one lesson for a plenary discussion, displaying their results of the two questionnaires and explaining the pedagogical approach, the objectives related to ICT tools in the sequence, and teaching complementary physics issues.

Observations

The table below presents the data gathered during the whole sequence. It includes the questionnaires before (number 1) and after (number 2) the sequence, the worksheet filled in by each of the 8 groups of students, and audiovisual records. The teacher's theoretical course given to this class and to another class of the same grade is indicated as data, because it provides information about theoretical knowledge students might use in their practical work lessons.

Data	Type	Level of analysis	Number of students
Questionnaire 1 (6 items)	written	individual	21 +15 from classroom 2
Worksheet for Microworld activity	written	group	24 (4 missing once)
Digalo map (6 items)	written +replay	group (sentence) $\frac{1}{2}$ classroom (map)	24 (2 missing once)
Audio records of the sequence (1 per group)	audio	group	24 (3 missing once) + teacher
Video records of the sequence (1 per $\frac{1}{2}$ classroom)	video	group	2 groups per lesson + teacher
Experimental report on the 6 items	written	group	24 (2 missing once) + teacher

Data	Type	Level of analysis	Number of students
Questionnaire 2 (6 items)	written	individual	20
Theoretical course given in parallel	written	2 classrooms	24 +15 from classroom 2

We only used a small part of these data for the results presented in this report, because more in depth analyses exceeded the short time frame of the project. Nevertheless, they constitute the main data of the researcher's PhD study, which is focusing on construction of knowledge through social interaction and argumentation.

5. Results

Social interaction and commitment to activities

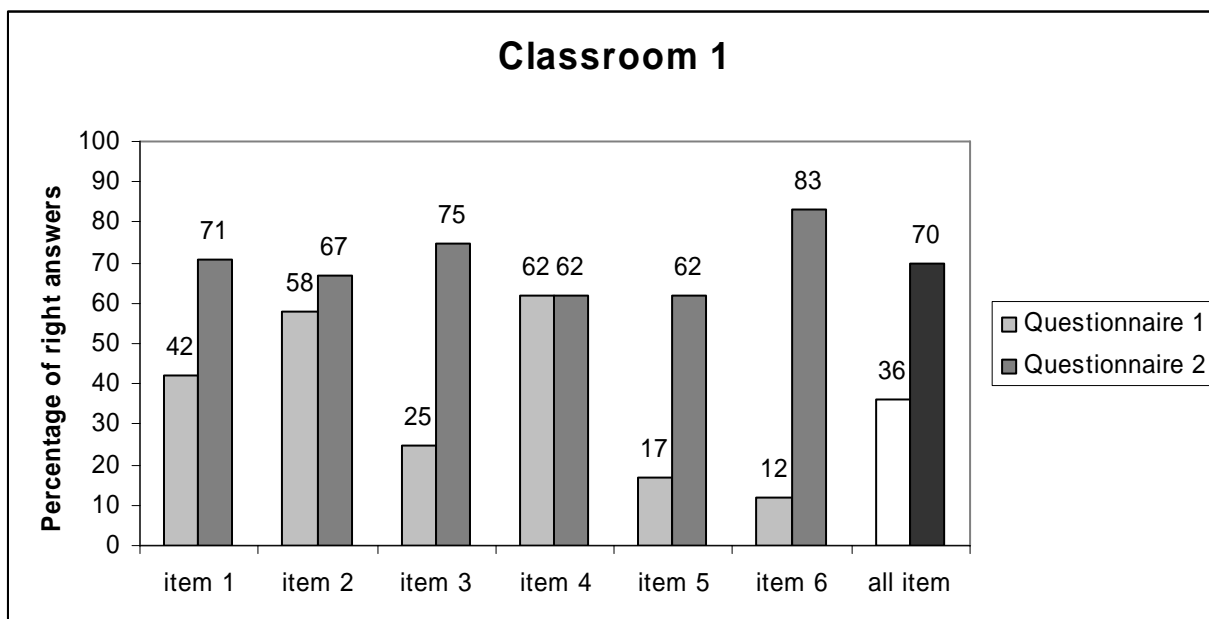
The groups displayed good and often very good participation in discussions, and most of them were focused on the activities. On the other hand, the transition between these rich discussions and the paper and pencil answers on the worksheet was problematic both for learners, who often failed to efficiently conclude their discussion, and for the researcher, who lost most of the richness of the oral discussion content. In addition, often only one student was in charge of playing the role of secretary for the group, which implied a more important loss. We observed that for the one or two groups lacking motivation to engage in discussions about physics, the disadvantage in learning was important, as the whole scenario was based on social interaction to build knowledge and foster understanding. These groups spent much more time idle or speaking about their life out of school than the other groups.

To evaluate the social interaction from the Digalo maps, we observed which kind of resolution strategies occurred when conflicting answers were shared on the map. We found both social resolution of conflicts and social construction of knowledge. The data do not allow us to support the idea that the Digalo tool fosters social construction of knowledge, but it does not hinder it. Digalo maps give an indication of the collective work and argumentative or inquiry moves. In almost all 12 maps, we found several groups justifying their conception of the situation. These justifications were often grounded in visible effects, or previous experience of a similar situation, and therefore can be considered as inferred from inquiry. Nevertheless, some justifications take a normative aspect and seem to come directly from theory, such as a specific law (i.e., "a falling object on earth always has an acceleration rate of 9.81m/s^2 "). Most of the Digalo maps also contain one or more interventions challenging another group's point of view, indicating an emerging argumentation. Nevertheless, these starting points of argumentative dialogue mediated by Digalo were not often answered by the groups holding the challenged conception. The dynamic of the dialogue appeared slowed down by the tool.

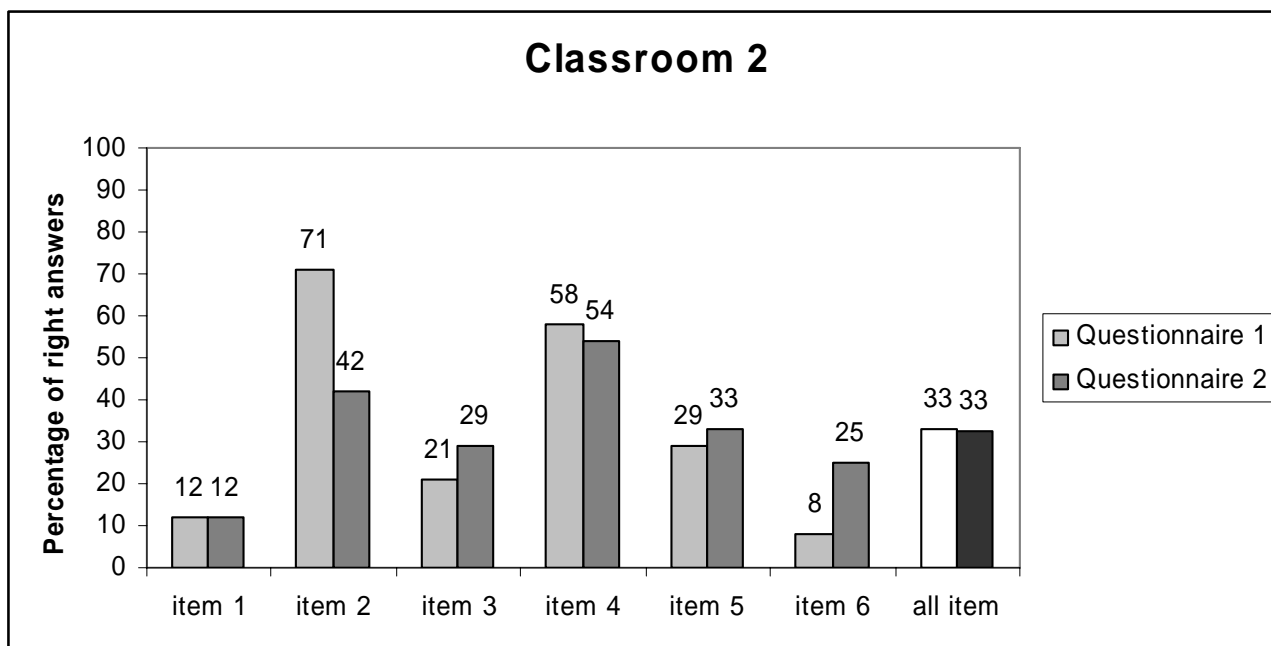
Preconceptions and learning

The preconception questionnaires filled in by students at the beginning and at the end of the scenario can offer a general indicator evaluating students' learning in terms of transformations of preconceptions in dynamics. The first and the second questionnaire presented the same six situations, highly related to known preconceptions dealing with acceleration and force, under a different presentation. Results show a clear improvement of the percentage of right answers for four of the six problems, and a rather constant

percentage for the other two items. The general percentage of right answers increased from 36% to 70% for all items.



These results indicate that something unusual occurred, as, according to the literature, the students' preconceptions normally do not change at all after six months of formal teaching. However, we need to compare this classroom to another classroom of the same college which also filled in the questionnaires before and after a six month teaching period. Theoretical courses were identical for both classrooms and were given by the same teacher, but the students in the second classroom did not have any practical work lessons. The comparison of the students' results in the second classroom on the first and second questionnaires corresponds to the state of affairs described in the literature in a traditional teaching situation: no change related to preconceptions is indicated. For four items the percentage is more or less similar for both tests, for one item the score notably decreased (item 2) and for the last item the score increased slightly (item 6) (see Figure below). The general percentage of right answers remains the same for the first and second questionnaires, 33% in both cases.



These results bear witness to a positive change in students' conceptions after the *Marbles move* case. However, two classes are never exactly the same and cannot be compared with the same validity as a control group. In addition, these data provide us with a very general evaluation of the ability of the *Marbles move* case to reach students' preconceptions in physics, but it does not provide information about which aspects of the case are responsible for this effect on preconception.

To proceed further in detail with this question, we propose looking more carefully at two items (numbers 1 and 3) of the questionnaire, in order to examine if and how students' answers on the questionnaire are linked to their work on the Microworld activity. This analysis can be done based on group worksheets through the identification of specific tasks on the worksheet which are directly related to the particular preconceptions questioned in items 1 and 3. The comparison of students' answers to the two related problems is grounded on the researcher's choice of a concept or piece of knowledge linking them. Two examples are presented here to illustrate this line of analysis.

Example 1

The questionnaire presented two balls suspended in the air at the same level, one heavy, the other light, and asked the students to decide wherever one is touching the ground before the other when we drop them, if yes which one, and why. The main issue in item 1 concerns the influence of mass on the movement. It is mostly related to an inquiry-based activity: observing the effect of the first variable, the mass, on the other, i.e., velocity or acceleration. This general observation can be made in different conditions; the two relevant conditions selected for our case were either a horizontal or a vertical free movement. The worksheet activity performed with the Microworld consisted of describing the influence of the mass on the movement of the marble rolling down the slope. It remains the same question as on the questionnaire, but presented in a more abstract way. The students were using the Microworld for a direct manipulation of the marble mass with the slide on the screen, and they observed the effect watching the simulation playing and reading the velocity measure. They then had to fill in a table with

the results and draw a conclusion answering the general question of the influence of the mass on each variable.

The table below compares the percentage of answers from the questionnaire's first item corresponding to the classic preconception to the groups' written answers on the worksheet about the question explained above. The answers were classified as "preconception" if they expressed the belief that the mass changes the marble's acceleration or velocity for an object freely falling to the floor. The percentage for the results on students' worksheet is approximate, because these data are gathered at a group level only.

Item 1	Questionnaire before	Results on the worksheet	Questionnaire after
Preconception	58%	about 20%	29%
Right answer	42%	about 80%	71%

The results on the worksheet are particularly good, probably because the activity consists mostly in observing the Microworld. However, these good results can be linked to the noticeable improvement on the second questionnaire for the same issue.

Example 2

Here, the challenge for physics learners is to differentiate Force from Velocity. This confusion can be easily demonstrated by asking the students which forces apply to a ball, when we toss it, at the precise moment the foot is still touching the ball, and when the ball is going up but already left the foot (see SESAMES case for more information). The classic preconception is to consider that there is a force applied to the ball by the foot even when they are not in contact anymore. Item 3 on the questionnaire displays a drawing of this movement in a three picture cartoon. Students had to draw a vector for the force applied by the foot on the ball in each picture. Observing the vectors and their directions we can distinguish between students' confusing the force with the velocity of the ball: the vectors are drawn on each picture and follow the movement direction. The correct answers mentioned only a force applied by the foot on the ball when it is lifting the ball and none when the ball left the foot and is going up. The activity with the Microworld asked students to draw the forces applied to the marbles at the very moment of the collision. The problem is closely related, but in the case of the marbles, the movement is horizontal instead of vertical. The table below shows the percentage of preconception, when force is confused with velocity, and of right answers.

Item 3	Questionnaire before	Results on the worksheet	Questionnaire after
Preconception	75%	about 20%	25%
Right answer with a wrong drawing		about 40%	
Right answer	25%	about 40%	75%

The results show that this problem was slightly more difficult. An intermediate level appears, where students cannot be considered confused by force and velocity: there is no force corresponding to the velocity drawn, but the expected force applied to each marble is inverted. The results from the worksheet and from the second questionnaire display a very similar proportion of preconception, and indicate that the level of understanding reached by the group working on the Microworld task and by individuals at the end of the

sequence is comparable. Even if these results require confirmation from more detailed and qualitative analyses of students' reasoning, we can assume that the sequence generally succeeded in reaching students' preconceptions and made our students work on their first conception in a way that they could use new conceptual tools in individual answers six months later.

The ICT tools in the case

Students were generally motivated to use the Microworld or Digalo technologies, even if they needed quite a long time to learn how to use them for the lesson's purpose (15-30 minutes). The observation of the phenomenon with the materialistic setting or in the Microworld was a real challenge for students. Careful and systematic observation seemed to be very unusual, and the basics of scientific procedure, such as manipulating one variable at a time in order to identify its effects, were far from being obvious. The simulation probably played the role of a much more reliable source of information for students than hands-on experience, as they used it as the unique means of inquiry. Nobody raised doubts on the validity of the model ruling the Microworld.

For students to learn how to use Digalo, the teacher's introduction to the tool was essential. Once students understood how to create a text box and to type their message in it, the discussion was dynamic. In about ten minutes, the four groups filled the screen with a map sharing their answers and initiating a debate. By choosing another "layer" active and visible on the same map, each group was free to go to the next question and/or come back to the previous ones for reading new messages. This advanced use of the layers did not happen often, probably because it was only the first time students had used the tool.

Students' evaluations

Students were asked to share their points of view on the sequence in a plenary discussion in the classroom. It appeared that most students underestimated the actual difficulties of understanding physics concepts in a way they would become able to use them for describing a situation like the marbles one. This fact led them to think they did not need to spend that much time on the *Marbles moves* case. To introduce the final plenary discussion in the classroom, the teacher displayed through beamer projection the Digalo maps produced during the argumentative activity and the quantitative results of the questionnaires. Then, the teacher presented the pedagogical approach used in the case, and explained his work on preconceptions. This presentation restimulated students' motivation towards learning. Six months after the end of the scenario, a short analytical feedback on the research results was given by the researcher, mostly based on Digalo maps. Students showed a real interest in these results.

Researcher and teacher roles

Most of the time the researcher was in the classroom during the lesson (doing the video and audio recording), and he could discuss what had happened with the teacher in training during the lunch break. He played a teacher role for the first lesson, and got the activity started. Thereafter, he only focused on recording, except occasionally giving technical support with digital tools to avoid overloading the teacher.

The supervisor kept an eye on the ongoing activities all the way through and participated briefly by helping to install Digalo on the local server, as he was the most experienced computer user. He asked the researcher to write a paper in the physics teachers' journal

for French speaking Switzerland. The interest displayed by a researcher in social sciences for the teaching of physics was an opportunity for him to send a meaningful message within the local political context. The researcher wrote an article describing the ESCALATE activity, and it was published and disseminated to all physics teachers in the French speaking part of the country.

The teacher in training worked as usual during the practical work lesson. His role consisted of introducing the activity, giving some hints or theoretical recalls, and then in visiting the different groups, one after another. During the group visits, the teacher in training usually repeated what had been said in the introduction, in an interactive way that visibly created a more mutual understanding between the students and him. In the second part of the lesson, the teacher in training was called by the groups in order to answer their questions, or confirm students' answers. In general, the teacher did not offer solutions to students' problems, but questioned them, guiding them to find out by themselves what the obstacle was. Although it was meant to be the only role for the teacher in the Microworld activity, video and audio records show it was not always the case.

Nevertheless, the use of technology requiring computers took a lot of time and attention from the teacher in training. His usual role of encouragement and assessment of the students' work during the practical lesson was sometimes restricted by this new load of technical work. This is important, as most of the female groups needed a word from the teacher to feel confident to take the next step into activities: they would not take the risk of starting on a wrong basis, and preferred to check their results by asking the teacher. Therefore, the groups were sometimes waiting for the teacher, who was very busy taking care of the technological and learning issues of four groups of students.

6. Lessons Learned

About designing the case and the Microworld

Designing is an interdisciplinary work, for which it is not sufficient just to put together specialists in their own activity field (teacher, physicist and psychologist in the present case). At least one person needs to be at the disciplinary crossroad herself, to ensure a successful communication in the collaborative and complex task of design. Indeed, the design of the sequence should provide a frame for students to engage in the co-construction of a specific set of knowledge, competences, and understanding. To illustrate the critical process of communication in this work, we present here the narrative of a situation which could have led to an impasse in the Microworld design:

The first interactions were between the researcher and the physicist, based on the willingness of the latter to help a young researcher. The physicist was very experienced both in describing a situation, as the *Marbles move*, with domain knowledge and in education through ICT. However, the required equation for the Microworld was not constructed easily. To follow the physicist's explanations, the researcher had to refresh to a high level of understanding his own physics knowledge, grounded in his previous scientific high school degree. Because referring to tables and formulas was certainly insufficient to be able to use the physicist's equation and explain it to the program developer, the researcher studied progressively an on-line physics course.

In the meantime, the dialogue started with the technical team writing the *Marbles move* Microworld in computer language. Graphics and global design were easy to share, but the transmission of the equation for the core of the simulation required an oral discussion

with an intermediate educator and the physicist who possessed the technical language and knew about developing the Microworld, its limits and its possibilities. Besides two short meetings between the educator and the researcher where they shared their understanding of the Microworld design, an intensive email exchange appeared to be necessary later for a problematic dimension: the collision elasticity.

The researcher sent a proposal for dealing with marble elasticity to the technical team and the mediating educator, as a new variable at users' disposal. The basic idea for adding this variable consists of a percentage of momentum getting lost in the marble's deformation during the collision. The collaborators replied, saying there were several ways to put elasticity into a mathematical equation, and asking for the physics theory grounding the proposal. The researcher couldn't answer and needed to call the physicist once more for help, who repeated his previous calculation with a little more detail.

Finally, the researcher understood, while studying the physicist's draft, that a mathematical simplification procedure was almost totally implicit in the physicist's reasoning, and he could then reconstitute the missing steps in the document. The researcher then sent this mathematical demonstration to the technical partner and the mediating educator. Thereafter, mutual understanding was achieved. This means that the real problem in the dialogue concerned proving that the physicist's mathematical approach to elasticity was correctly referring to domain knowledge, and not with managing technical challenges. Finally, the developer could consequently add the variable of elasticity to the Microworld.

About implementing the project objectives

The rich thinking and argumentative content of the groups' discussions does not fit into the actual way of evaluating physics. This was a limitation to our work, as the teacher had to evaluate his students based on the traditional way of teaching, given in parallel, rather than on the time consuming activity he carried out with them. It is a limitation for all teachers and it makes them hesitate to engage in a comparable innovative practice, since they would have to involve a lot of lessons and effort into a none valued work. In consequence, we claim that it is necessary to develop new ways of evaluating which match the needs of innovative practices . Therefore, we could not provide a serious evaluation of the students' learning in the case without analysing audio and video records.

About using ICT in the classroom

During the activities, once contact is established with the students, it is important to attend the lessons to make sure the teacher and the students know how to use the material, the software, and to be able to notice or even intervene when something does not happen as it was expected to. The designer of activities is the one in charge of acknowledging if the prepared scenario is being implemented the way it was meant to, because the teacher cannot be expected to notice all crucial points of divergence when he has not designed the case. Before the activities start, the technical issues must be prepared: installing the Microworld on the school's computers and putting Digalo into the local net for having synchronous sessions; preparing the material for video and audio recording (which needs students' written authorisations).

About learning objectives

The project timetable was unfortunately too short to implement a sequence using Microworld in the genuine sense described by Papert, as "knowledge incubators". Indeed,

the technological development of *Marbles Move* was reduced to a few months to leave enough time for collaborating with the teacher and carrying out the implementation at school. Therefore, both the Microworld and the sequence design were too short to realize a device offering students the possibility of exploring various models of movement laws. It would have been the case if students could have engaged in changing the Microworld and creating other possible worlds respecting different physical laws than Newton's. To drive the design and implementation process further on this line is certainly an interesting follow up to this ESCALATE case.

The Microworld underlying model should be more explicitly discussed, as it is very easily taken as the truth by students. Rather, having a Microworld at one's disposal should provide an opportunity for learners to understand the roles that scientific models play in physics. The learners should become more aware of how a model works to represent a natural phenomenon. They could then use the Microworld as one model among many, in the frame of which their inquiry takes place. On this basis, the model could be presented all at once as a useful representation for understanding, as a relevant knowledge, and as a simplification and reduction of reality that can be misleading or insufficient in certain situations.

Studying the role played by argumentation in the learning process requires a more detailed work on the audio and video records collected at each step of the sequence.

8.5 Case E: the Light

Luca Tateo and Antonio Iannaccone
(Department of Education Sciences, University of Salerno)

1. Introduction: the elaboration of a new scenario

The context

The Department of Education Sciences (DSE) research unit at the University of Salerno carried out experiments with Digalo and dissemination activities involving science teachers in junior secondary schools.

First, all ESCALATE contact materials (project descriptions, contact letters, parental authorizations, etc.) and research instruments (questionnaires, scenarios, etc.) were translated into Italian. The translation of the instruments presented some difficulties, because several questionnaires' items were context-specific, so alternative solutions had to be found in order to comply with the Italian cultural context.

Experiments were carried out in junior secondary school classrooms (grades C1-C3, students' ages between 11 and 14). DSE researchers had some meetings with 3 junior secondary school principals in Baronissi, Avellino and Forino, and with some science teachers from the same schools. Researchers illustrated to them the rationale of the ESCALATE project and the idea of developing argumentation in science learning supported by the software. The feedback was very positive, and the teachers seemed very interested in using such an educational approach in their own science curricula. Thus, the next step consisted of selecting teachers, with respect to the time constraints, the school context and the teachers' ICT expertise. DSE researchers also verified the availability of computer laboratories and the HW and SW equipment. Because of logistic and organisational constraints, DSE decided to focus the experiments in classrooms in Avellino.

Two teachers were involved in the process of designing a brand new scenario. The teachers' main remark about the ESCALATE's experimental protocol was about the selected scenarios. In fact, the proposed scenarios – Euglena and Storms – didn't fit very well in the Italian junior secondary sciences curricula.

The title of the pedagogical scenario, designed in collaboration with the teachers, is "The Light". The objective of the scenario is to develop knowledge about light, about its double nature of wave and corpuscle, and about the colours' theory and its effects of light on human life. DSE had to modify the ESCALATE scenario and activity protocol with respect to the new topic (see annexes). The first activity in the classroom was planned for April 2007, after Easter holidays.

The theoretical framework

Computer supported collaborative problem-solving in science curricula is a learning situation that is often studied by the psycho-pedagogical approaches inspired by the theoretical models of socio-constructivism (Baker, Quignard, Lund & Séjourné, 2003; Clark, Anderson, Kuo, Kim, Archodidou & Nguyen-Jahiel, 2003). Within this framework, collaboration is a way to organize the social interactions with respect to meaning-sharing and knowledge building (Johnson & Johnson, 1987; Perret-Clermont & Nicolet, 2001; Slavin, 1989).

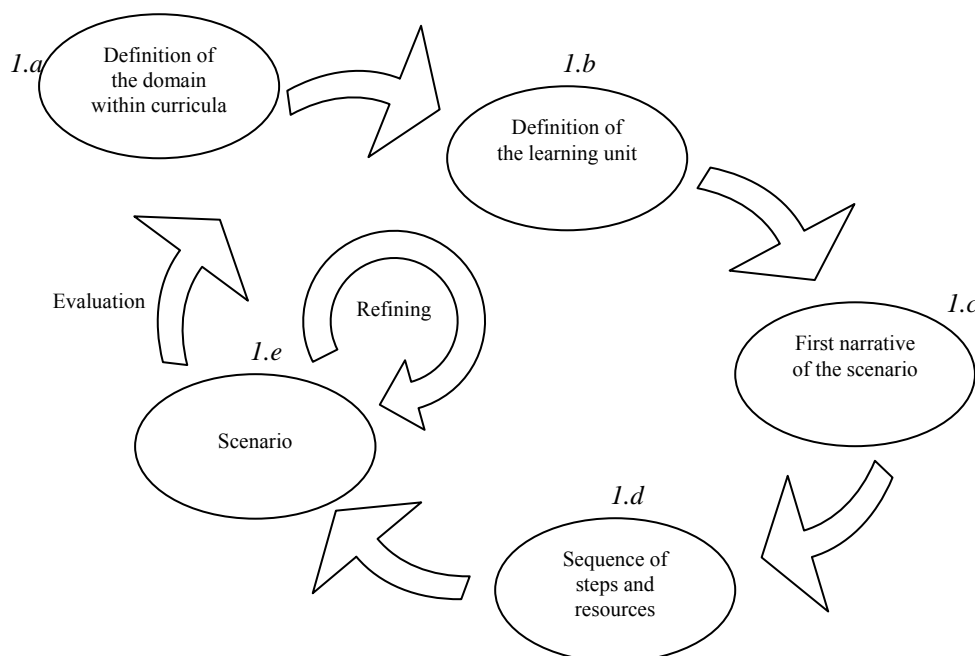
The scenario-based approach is often used in educational research projects as an analysis, design and operating methodology. Nevertheless, it is mainly used analytically, as a tool for capturing teacher and classroom practices, designing new activities and formalising them in CSCL educational situations (Pohl, Dubois & Heymans, 1998). Less attention is paid to the implementation of didactic activities that could blend the face-to-face *and* computer mediated collaboration activities in the classroom.

In the context of the ESCALATE project, DSE aimed at designing and experimenting with a learning scenario exploiting the resources of both of those interaction modalities of collaborative learning. The ESCALATE rationale that argumentative discussion is a basic feature of learning science by reproducing the expert researchers' way of working has been embedded in a classroom context where researchers tried to anchor the proposed activity to the teacher's expertise and the students' capabilities.

The methodology to collaboratively design the scenario

The collaboration process between researchers and teachers is crucial to the development of a scenario-based working methodology. During DSE experiments, teachers always played an important role during the activities. Researchers and teachers worked together to design the scenarios. The teacher's great knowledge of the classroom and teaching practices were important to tailor the scenario to the students' real learning needs. Figure 1 shows the steps of the collaboration process between DSE researchers and teachers in designing the scenario.

Figure 1: The circular collaborative design of pedagogical scenarios



In a preliminary activity, DSE researchers held face-to-face meetings and e-mail exchanges with teachers to plan the experiment, to define the objectives, and to embed the collaborative problem-solving activity into curricular lessons as much as possible (Fig 1.a). The learning domain was thus chosen – natural sciences and physics - and the

teachers were asked to propose some topics for the lesson to be implemented into the scenario (Fig. 1.b).

Once the topic was chosen, a first narrative draft of the scenario was designed and discussed with the teachers. The first draft outlined the general learning goals, the topic, the students' prerequisites, and the activity structure (Fig. 1.c). The objective was to define the limits of the learning unit to be implemented into the scenario. In principle, a scenario could indeed cover a single topic during one session or a more complex and multidisciplinary topic to be developed during different sessions.

In this case, the scenario covered a sequence of three lessons of about two hours each. This duration included the preparation, the experiment with Digalo, and the final debriefing with the classroom.

Once the learning unit was defined, the teacher prepared an introduction to the topic and the materials to be distributed during the lesson and shared them with the researchers in order to define the set of resources to be included in the scenario (Fig. 1.d).

The final step was to refine the scenario and to detail each single step. The collaborative design process led to the final version through a recursive sequence of more accurate and fine tuned definitions (Fig 1.e). This process was mainly based both on the teacher's knowledge – of the topic, the classroom context, best teaching practices, etc. – and the researcher's experience – of the previous experiments, the didactic situation, the scenario's structure, etc.

2. Description of sessions' preparation and execution

The session preparation and the execution of the experiment based on the scenario designed with teachers will now be presented in order to elaborate some reflections. The scenario was designed with the objective of developing knowledge on light, its double nature of wave and corpuscle, on colour theory, and effects of light on human life. The scenario was a form of sheet music or a screenplay (Dillenbourg, Schneider & Synteta, 2002): a general activities guide for teachers and learners that can be tailored to the specific needs of a given classroom.

Background

The junior secondary school "Leonardo Da Vinci" is located in the central area of the town of Avellino. The DSE has signed a collaboration framework agreement with the school in order to carry out experiments in computer supported learning activities.

This collaboration required the Italian translation of all ESCALATE contact materials (project descriptions, contact letters, parental authorizations, etc.) and research instruments (questionnaires, scenarios, etc.). As already mentioned, the instruments' translation process was difficult because some of the questionnaire items were context specific, so we had to find alternative solutions to fit with the Italian cultural context.

The collaboration with the science teachers in Avellino started with an informal meeting to illustrate ESCALATE's objectives and work plan and to illustrate Digalo. The teachers were very interested in the project but immediately raised some problems with respect to the scenarios used in previous experiences: Euglena and the Storm. One of the teachers

objected that these topics were already known to her students, because they were in the curriculum of the previous grades (B5-C1). So researchers proposed finding a topic to design a brand new scenario. The teacher suggested some questions rose in a classroom discussion with students. Thus, a second meeting was planned, and the teacher was asked to imagine in the meantime how this topic could be transformed into a lesson.

During the second meeting, the collaborative design of the new scenario started and was elaborated during further e-mail exchanges. Researchers and teachers planned to carry out two sessions, according to the timing proposed by previous ESCALATE partners' experiences. Then DSE researchers visited the school to install Digalo and arrange the computer lab. Some problems with the computer network were found, and researchers had a bit of trouble fixing them.

During the first session – front lesson and individual study – researchers immediately realized that two sessions were not enough and an additional session was planned. A short description of the sessions follows.

Observations

During Session 1, two researchers and the teacher presented the activity to the students. A pre-test was submitted, then the teacher started a front lesson about light and distributed some didactic material from Wikipedia and textbooks. After that, the students worked individually with pen and paper and studied the materials. They were allowed to take notes on the documents (Figure 2).

Figure 2: students during the individual study phase



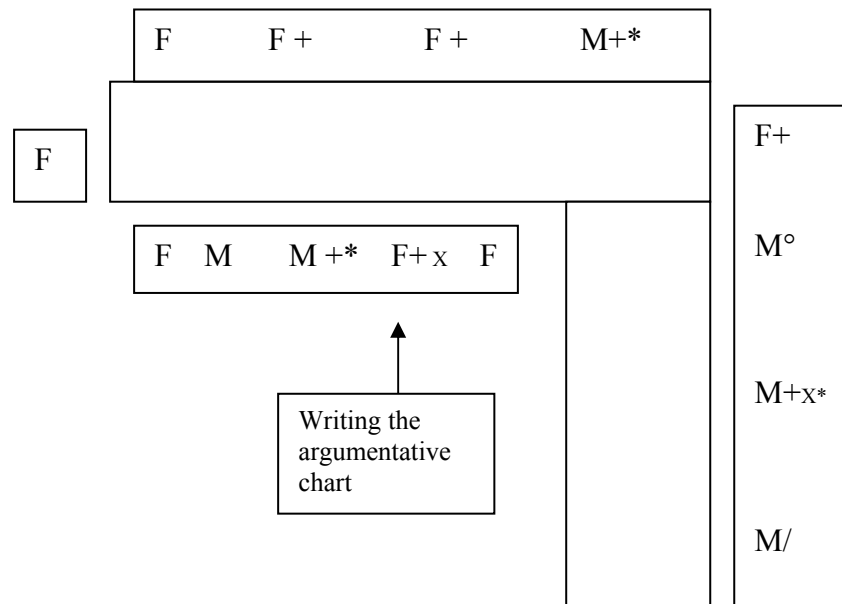
During Session 2, the classroom was divided into two groups, according to the pre-test results, and they worked in separate classrooms. The teacher gave them back the material they used in the 1st session. One group was followed by the teacher and a researcher who video-recorded the interaction. The students sat in the way shown in Figure 3.

Figure 3: 1st of the 2 groups at work



The second group was followed by two researchers' audio-recording the interaction and taking field notes. A short description is provided of what happened during the interactions of the second group in order to provide more detailed information about group working and the classroom context. The students were sitting around the desks as shown in Figure 4 (M for male, F for female).

Figure 4: 2nd group students' positions around the desks



At the beginning students felt uncomfortable in front of the researchers and the audio recorder. But after a little while, they started the discussion with a good number of interactions among the participants. Only student "M/" showed a peripheral participation, paying attention to the activity but remaining silent. Students marked with "+" showed a more active role during the interaction.

The group had to agree upon the answers to the pre-test questionnaire about light (see annex 2). There were many contributions with respect to the choice of the more suitable terms to be used. The discussion became animated when they dealt with the problem of dark and light colours.

Student “M+X*” often played the role of summarizing and telling the girl in charge of taking notes what the group agreed to write down. The procedure adopted by the group seemed to be finding the information needed in the didactic material they had at their disposal, and trying to provide clearer and shorter answers. When the teacher entered the classroom to check the work, students didn’t ask her questions, but they seemed interested in her suggestions. Sometimes, they became aware of the recorder but agreed to ignore it and made adjustments in the conversation to help the recording.

Student “M” had a playful attitude - jokes, digressions, etc. – that didn’t seem to affect the group work and the execution of the task.

At the end of the activity, some students stood up and decided to read aloud the document to verify each single question. The student reading frequently asked the others if they agreed upon the content. Some students were not satisfied with the answer to question # 4 and decided to go back to it. Students marked with “*” stood behind the others, and one of them reread the didactic materials looking for a more compliant answer to question # 4. The document was not basically modified, but some contributions were aimed at identifying someone on whom to place the responsibility for the incomplete answer. The argumentative chart was signed by all the students. A student took the recorder and left a greeting message, then invited others to do the same. Many students recorded their message using a nickname.

Session 3: The students worked in the Education Sciences Faculty’s computer lab, because the school lab network was out of order. Students were dispersed in four rows – one student for each computer. One researcher explained Digalo and started a short training session. A second researcher video-recorded the activity. Two teachers were present but they didn’t intervene often.

The discussion session was carried out using 4 shapes, 3 connectors and 4 layers, one for each question students had to answer (Figures 5 and 6).

Figure 5: Digalo screenshot of discussion about the 1st question

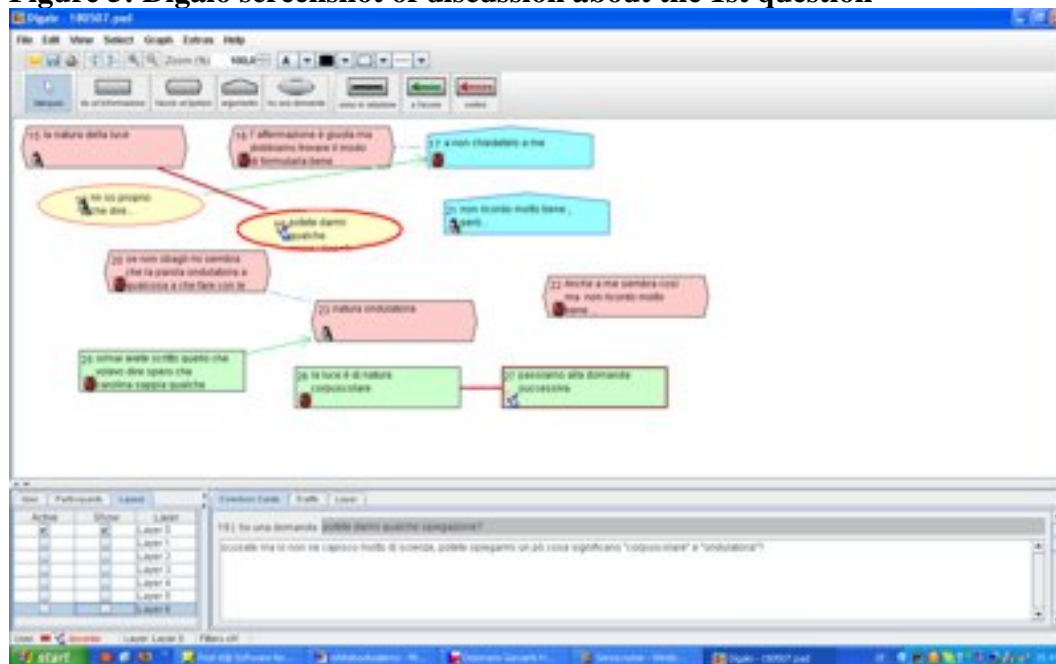
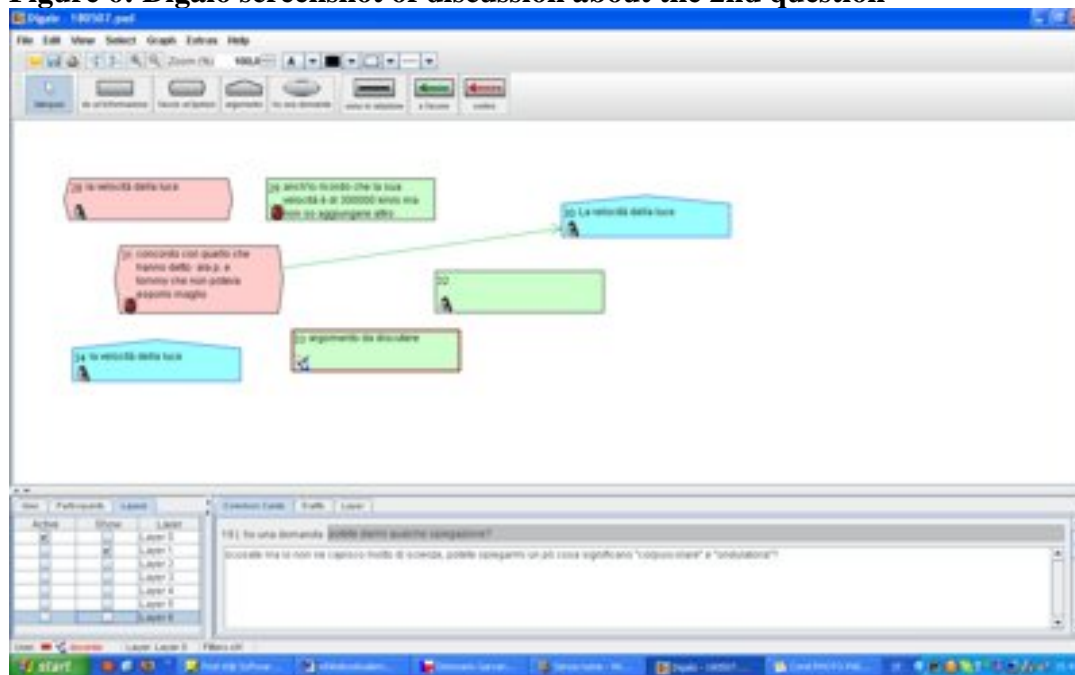


Figure 6: Digalo screenshot of discussion about the 2nd question



After the Digalo session, a short debriefing and the post-test submission took place. During the discussion, some interesting points emerged. The first phenomenon researchers observed was that the degree of participation was strongly influenced by the students' expertise in typing on the keyboard. Those students that could type faster were the main contributors. The result is that the argumentative diagrams are not fully populated. On the other hand, as Digalo is not very intuitive, the users tended to avoid using connectors and created the relationships between shapes by placing them in a sequential order.

The teachers had a generally positive attitude towards the experience and the use of Digalo. But they were not as participative as in the design phase and in the face-to-face sessions of the scenario. This is probably due to the lack of familiarity with the computer supported collaborative activities.

3. Difficulties encountered

From the experiment, researchers learnt that the actual implementation of the activity in a classroom requires at least one session per week for three weeks. Students need to familiarize themselves with the software and to elaborate the knowledge as they learn it in the classroom. Thus, the experiment covered two sessions in the school and a final session in the computer lab at the University of Salerno, in order to better control both the setting and the computer network reliability. All the sessions were video recorded.

During the Digalo session, researchers observed that students did not use connectors very well. They spontaneously connected shapes by placing them in a sequential order, rather than in a conceptual map style. Another problem arose with the teacher's lack of familiarity with the software supporting collaborative learning.

8d.1 Concluding remarks

The experience of the DSE research team in the classroom of Avellino led to some interesting points, with respect to the collaboration process, in order to achieve ESCALATE's goals.

From this experience some conclusions can be drawn:

- The scenarios must be designed in order to include more sessions. First of all, students need to practice with the software in order to achieve a high level of expertise and to fully use its features. Secondly, they need more time to elaborate the new knowledge and to reflect upon it. Then they have to be able to do their own home study, search for new information and maybe freely discuss it.
- The teacher has to be trained to use Digalo in order to understand its potential, the appropriateness of the tool, and to adapt teaching to it. Otherwise, the effectiveness of computer-supported collaboration in the classroom is put in jeopardy, and it becomes a traditional lesson with the flavour of technology.
- The process of co-designing the scenarios with the teachers has many advantages. First, it leads to a deeper involvement and motivation of the teacher. Secondly, it allows to better situate the use of argumentation in the curricula activities and in the classroom. It also requires a continuous dialogue between teacher and researcher in order to develop a feedback circle: a scenario is not a fixed script but a guide for the activity.
- The evaluation of learning is not immediate. The pre-test/post-test procedure might not prove useful to assess students' learning.
- There are three layers of learning affecting the didactic sequence: 1) pedagogical, 2) technological and 3) knowledge. From the pedagogical point of view, students must be familiar with collaborative learning and argumentation. Otherwise, they are not able to take maximum advantage of the educational activities supported by Digalo. Then they have to practice with the technological artefact, or else they cannot fully express their arguments in a graphical discussion. On the knowledge layer, the activity must effectively support students to reach the learning objectives and to elaborate new knowledge and meta-reflections.

Some new research questions were raised from the experience with “The Light” scenario. For instance, what would happen if the scenario were designed in such a way that students didn’t receive a preliminary lesson? Could the activity be more effective if it had started with their common sense knowledge, carrying out a sort of progressive inquiry?

6. Annexes

6.1 Annex 1

Didactic activity: The light

General objectives

The activity is structured in several steps, including classroom work, group work, plenary discussion and individual work.

The activity allows each student to acquire the new knowledge elaborated in small groups and supported by the argumentative discussion and the study of materials.

For some students the discussion is mediated by Digalo, enabling to visualize the argumentative flow.

From a complex question (*What is the light?*), students elaborate hypotheses and arguments. They use the documents provided by the teachers. In debating with other students defending a different standpoint, they build knowledge about the topic of light's nature and its effects on human life.

Learning objectives

Developing new knowledge about the light, the corpuscular or undulatory nature of light, the colours, etc.

Description of the activity

First session: steps 1) to 7)

Second session (one week later): steps 8) to 12)

First session:

- 13) Teachers welcome students and present the researchers.
- 14) Pre-test: Individually, students fill in a short questionnaire on pre-conceptions (see annex 2, answers will be used to form groups)
- 15) Teachers present a short description of the activity (general information about the goals, the steps and the organisation of group working)
- 16) The teachers introduce the phenomenon of light (front lesson)
- 17) The teachers illustrate the documents provided to the students
- 18) Students individually study the documents, they can take notes (individual task)
- 19) Group formation, the teacher and researchers elaborate questionnaires during the individual task and group students in such a way that students with different pre-conceptions discuss in the same group

Second session:

- 20) Preliminary group working: the classroom is split into small groups (2 or more groups of 7/9 students). They have to elaborate the list of arguments supporting their positions with respect to the specific question elaborated by the teacher (see annex 2)
- 21) Presentation of Digalo
- 22) Plenary discussion (with Digalo/without Digalo)
- 23) Post-test: individually, students answer a short questionnaire
- 24) Debriefing: final classroom discussion about the experience

6.2 Annex 2

Scenario 3: the Light (Guidelines for the teacher)

General presentation

As a complex phenomenon, the light represents a very interesting learning subject.
Find more information on Wikipedia: <http://it.wikipedia.org/wiki/Luce> and related links.

Pedagogical objectives

Developing new knowledge about the light, the corpuscular or undulatory nature of light, the colours, etc.

Developing the capacity to argue in a scientific subject, supporting standpoints with the knowledge and the data acquired during the study

Scenario structure

- 11) A short welcome (don't say too much at the beginning because we would like to know the students "pre-conceptions" with respect to the topic)
- 12) Pre-test: Individually, students fill in a short questionnaire answering the following questions:

Please answer the following questions.

Name:

Birth date:

Classroom:

Where do you live?

For you, what is the light?

- g. Is light made of waves or particles?*
- h. How fast is the light?*
- i. What colour is light?*
- j. Where and why do rainbows form?*
- k. Why does sunlight darken our skin?*
- l. Why do people in the desert wear white?*

Thanks!

Do not forget to gather questionnaires and keep them accurately!

- 13) A few words to thank students and present the follow up to the activity (general information about the goals, the steps and the organisation of group working)
- 14) General presentation to the classroom starting with some documents or a power point
- 15) Forming the groups as a function of the pre-test answers (in such a way as to have relatively homogeneous groups with respect to their standpoints; during the discussion, groups defending different hypotheses can be combined)

16) Group working: elaboration of arguments and writing of the “argumentative chart” with respect to the following questions (to be adapted to students’ knowledge level):

- | Does light have a corpuscular or undulatory nature?
- | From what does the speed of light derive?
- | From what do the colours of objects derive?
- | Why, since exposition to light is equal, do some objects warm up more than others?
- | How does melanin work in our cells?

17) Presentation of Digalo

18) Classroom discussion with Digalo: groups debating on the same 5 questions

19) Post-test (some additional questions can be included!)

Please answer the following questions.

Name:

For you, what is the light?

m. Is light made of waves or particles?

n. How fast is the light?

o. What colour is light?

p. Where and why do rainbows form?

q. Why does sunlight darken our skin?

r. Why do people in the desert wear white?

Thanks!

20) Final debriefing about the experience

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