ESCALATE: The White Book

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Part I: General Introduction

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Chapter 1: General Introduction

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1.1 The objective pursued in the ESCALATE project

It is recognized that Science Education should promote understanding of scientific concepts and scientific practices instead of the acquisition of scientific facts. This general claim which is agreed upon most of educationalists, researchers and policy makers is not a trivial matter when it comes to find strategies to lead to such goals. Researchers in Science Education have claimed that argumentation may foster the acquisition of scientific concepts. However, engaging in scientific argumentation is a difficult endeavor. The use of enquiry-based strategies may provide procedures that sustain argumentative practices. However, it is difficult to design activities that combine argumentation and enquiry-based strategies. The pedagogical idea brought forward in the ESCALATE project was to bring technology to the service of education so to provide environments that make the integration between argumentative and enquiry-based strategies possible.

The ESCALATE project capitalizes on two environments that mediate argumentation and enquiry-based practices. Argumentation is enabled by the Digalo tool that has been developed in the DUNES project (IST-2001-34153), in which some of the participants in this SSA were involved. The Digalo tool provides a graphical platform in which participants may collaboratively construct an argument (on one computer or on different computers in a-synchronous mode) or participate in synchronous discussions. The argumentative map produced during the construction or during the discussion is an artifact that participants can exploit in further activities, as opposed to face-to-face discussions from which students cannot "physically" extract previous outcomes.

The second tool is in fact a series of tools – Microworlds, that fit ideas developed by constructionists, and that are alleged to enable learning through construction, bricolage, and "instrumentalizing" (transforming an artifact into an instrument, through which meaning is mediated) .Microworlds are open to manipulation, construction and de-construction of virtual objects as well as their behaviors and the relationships between them. Microworld are open for the students, allowing them to change, for example, the initial conditions of a physical phenomenon, isolate a specific factor and see how it influences a certain physical procedure, etc. In that sense, students can define the physical laws that dominate the phenomena, they can use the trial and error method to examine “what will happen if…”, and they can transform the environment “so that … will happen”, etc. Microworlds such as those developed in the Learning Games project (LeGa, Greek Secretariat for Research and Technology, GSRT-03-26) that feature a 3D modeler for students to experiment and express their ideas, are available to students.

1.2 Specific objectives

If the general approach of the ESCALATE project is quite simple – the integration of argumentation and enquiry-based activities in the same environment is a difficult enterprise that necessitated an SSA project: In ESCALATE, we integrated the enquiry-based and argumentative-based approaches and use the technological tools we independently developed *in conjunction* - in classrooms and in other, informal learning environments like museums. More specifically we employed the research results of the DUNES and LeGa projects and implemented them in different educational frameworks. A well-designed learning environment was then necessary. We detailed this general objective as a list of operative objectives:

(1) Implementing our approach to science learning and teaching, through the design of learning environments, by means of state-of-the-art of argumentation-based methods and tools, especially the ones developed in the DUNES project.
(2) Using technological tools – mainly "Microworlds"- designed to enhance science learning environments and by which students engage in representation, construction and experimentation with digital artifacts.
(3) Conducting the implementation of (1) and (2) above in the framework of several schools, science museums and other science learning environments in 5 countries: France, Greece, Israel, Switzerland and UK.
(4) Creating a "critical mass" of teachers, through proper training activities, who are capable of maintaining the argumentation-based science learning environments during and beyond this project's life.
(5) Compiling and analyzing all the data gathered and preparing a comprehensive volume describing the experience and issuing recommendations to guide the launch of similar initiatives elsewhere in Europe.

For the accomplishment of these primary goals, additional objectives were addressed, including:

- The design of "cases" to support learning activities featuring argumentative discourse in science.
- The design of computer-based educational scenarios to support enquiry-based learning combined with argumentative discourse in science.
- Training science teachers to design, animate, and evaluate argumentative activities, based on the above, in classrooms, science museums and other learning environments.

The accomplishment of the primary objective of the project – building a usable and effective learning environment that enhance science learning could not be easily measured or compared with any predefined magnitudes or criteria. The whole concept was very much a new one. We nevertheless developed measures that pointed at success or failure of the implementations in the different sites. The ways used by the different were diverse, some adopting qualitative methods, and some quantitative ones. We list here some of the ways we used to evaluate accomplishments:

(1) A first measure consists of listing the number of educational-science-activities created and implemented within the current science curriculum;
(2) Another measure refers to the number of teachers and students that used the proposed tools and methods in their science teaching and learning.
(3) We also evaluated the level of students' engagement (involvement) in solving scientific problems and discussing scientific conceptions.
(4) We evaluate the use of **scientific language**, a language that incorporates daily life speech acts (e.g., questioning, agreeing, objecting, clarifying or elaborating) with scientific speech acts (e.g., challenging, counter-challenging, refuting or appealing for different kinds of resources) by various students.
(5) In certain cases we used statistical methods to measure changes in mental models of scientific concepts before and after implementation of cases, or to measure the effect of some manipulations (such as the mediation of the teacher)

1.3 The White Book as a resource for researchers, educators and teachers

The White Book is aimed at integrating in one unified volume all the experience gathered by the partners in their respective countries, including a comprehensive account of the preparatory work, the activities themselves, the interaction with the community of teachers and an overall evaluation of the work and its outcomes. This ESCALATE White Book includes also a thorough analysis, by the partners, based on a macro-, project-wide perspective, from which useful recommendations (to teachers, educational authorities, other public and private players in the learning/teaching arena) is articulated. A member of the Swiss team visited all learning sites to observe in vivo how children learn in the new integrated learning environment and to report on differences of implementation. This White Book represents the means through which our project's heritage will be transmitted toward its further implementation elsewhere. The report, devised for unrestricted distribution, will undoubtedly constitute an important building block on the way to achieving the big impact we intend to generate in science learning all throughout Europe. This white book presents the theoretical back up of the project (chapter 2); the technological advances (Dunes-Digalo, Microworlds) on which it could rely and that have been adapted (chapter 3); and the best cases developed in the Escalate project (chapter 4). Then chapters 5 to 9 explore all the partner's experience with these cases in their respective countries, including a comprehensive account of the preparatory work: what strategies, methods, cases, have been designed, implemented, tested, then redesigned, evaluated and disseminated; how the teachers' roles have evolved during the course of the implementation; and also the participants' opinions. Attention is brought to the necessary adaptations required to meet the demands of the different realities of our European schools to implement the tools, cases and evaluations. This awareness makes Escalate a multidimensional project in which stimulating cross-fertilizations among the partners has occurred. Chapter 10 presents an integrative view of the findings, pedagogical lessons, and recommendations concerning sustainability and scalability of the project to propose a new model of Science Education in classrooms and informal settings.

The overall impression is that an inquiry based approach in the teaching of science that gives a large role to the learning of argumentation is perhaps difficult to implement in its first steps, but then very quickly releases interest (and some time enthusiasm) on the side of the learners and the teachers. In this endeavor the use of a tool that sustains the visibility of argumentation (Dunes/Digalo) is a very precious and innovative step. As well, the tool Microworld that offers simulations creates bounded environments that permitting systematic exploration and hypothesis testing by the students, an epistemic agency that they don't experience in schools usually in the learning of science. This approach has also allowed for an increase in the social exchanges between the students (group work, debates, and other forms of joint activity and social interactions).

Of course introducing such tools and teaching strategies is a complex endeavor. The close examination of each trial and experimentation in different contexts, has taught us lessons on how to proceed. Designs have to be adapted, students and teachers' scripts are transformed, learning is not automatic but the result of a careful preparation and ever present monitoring from the teachers; evaluation needs to take into new dimensions (time devoted, technological know-how, nesting in the curriculum, teachers' motivations, freedom and previous training, classroom organization, institutional support). Escalate has experienced very different opportunities of implementation of the « cases » , different ways of doing it, different meanings attributed by teachers and students to these activities, different settings and conditions (both physical conditions and psycho-social conditions). Escalate has brought data and insights on the interrelations between the « micro » level of making cases, training teachers etc… and the « macro » level (institutional conditions, cultural and professional traditions, interpersonal relationships, image of science, etc.) that mediate the acceptance of such cases, trainings, etc., that have contributed to the difficulties and success of Escalate. The set of recommendations drawn from these experiences described in chapter 10, may stimulate « spin offs » to be born from Escalate!

General plan of the White Book

Part I: General introduction in which the content of the book is expressed, as well as general themes announced.

Chapter 1: General introduction

Part II: This part includes a theoretical background on which the ESCALATE project relies as well as a background concerning technologies and tools at disposal.

Chapter 2: Learning Science in Inquiry based environments and in argumentative activities

Chapter 3: Technologies:
The Dunes environment and Microworlds

Part III: The design of cases.

Chapter 4: The design of cases

Part IV: The description of the respective implementations and lessons learned (**France, England, Greece, Switzerland (& Italy), and Israel**). After a brief introduction, each of the teams will describe its experimentation(s) (chapters 5 to 9).

Chapter 5: Description of the experimentation in France

Chapter 6: Description of the experimentations in England

Chapter 7: Description of the experimentations in Greece

Chapter 8: Description of the experimentations in Switzerland (& Italy)

Chapter 9: Description of the experimentations in Israel

Part V: General reflections on the main outcomes and overall picture of the respective experimentations. This concluding chapter will also include **recommendations** for further activities integrating inquiry and argumentation based environments for Science Education.

Chapter 10: Reflections and recommendations

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Part II: Theoretical Background

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Chapter 2: Theoretical background - Learning Science in Inquiry Based Environments and in Argumentative Activities

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2.1 Theoretical background: a shift in Science Education towards construction of knowledge and scientific habits of mind

A trend in science education is the move away from the implementation of lessons that seek outcomes related exclusively or predominantly to students' concept learning. While the traditional alternative for concept learning has been process learning, newer ideas and beliefs in cognitive and social psychology speak to the importance of instructional sequences/units that seek outcomes related to students' reasoning and communication or students' argumentative activity in science contexts. Recognizing that science education is more than concept learning, forward thinking policies and recommendations are advocating learning how to do science and learning about the nature of doing science (Hodson, 1992; NSES, 1996). Research on learning and the implications it has for the design of learning environments (Glaser, 1994) strongly suggests that concept learning take place in a context that also supports the development of tools, criteria, standards, and rules students can use to investigate, represent, communicate, assess, and evaluate knowledge claims. The language of science is not exclusively the enunciation of terms and concepts, facts and laws, principles and hypotheses. The language of science, owing to the restructuring character of scientific claims about method, goals, and explanations, a character firmly established in the history, philosophy and sociology of science (Duschl & Hamilton, 1997; Hodson, 1985; Schwarz & Glassner, 2003), is a discourse that critically examines and evaluates the numerous and at times iterative transformations of evidence into explanations.

Focusing on the goal of developing students' habits of mind that facilitate both an ability to construct scientific knowledge arguments as well as to evaluate the claims constructed, researchers (Brown, Collins, & Duguid, 1989; Duschl, 1998; Krajcik, et al, 1994; Penner, Lehrer, and Schauble, 1997; Roth, 1995; White & Frederickson, 1998) have begun to focus attention on the need for learners to engage in sustained long term inquiries. Long-term inquires, full inquiries, or as Schwab called them "invitations to inquiry" create affordances for several kinds of learning that shorter discrete lesson formats do not. Specifically, the long-term inquiries create opportunities for learning to focus on the conceptual, notational, and epistemological dimensions of reasoning and communicating in a knowledge domain (Gardner, 1991). Or, as stated above, concept learning can be situated in a context that also supports the development of language, tools, criteria, standards and rules students can use to investigate, discover, represent, communicate, assess, and evaluate knowledge claims.

Hence a concomitant goal for the development of instructional units is to facilitate formative assessment opportunities. The ability of teachers and researchers to understand how to move learners along in the development and acquisition of conceptual, notational, and epistemological knowledge is seen as paramount to educational improvements (Black & William, 1998). The design of science learning environments that support the development of learning science reasoning and appropriation of tools and language for doing science are frequently situated in task environments that require epistemic reasoning. Penner, Lehrer, and Schauble (1997) used models and model building as the epistemic context for coordinating the curriculum, instruction and assessment frameworks on investigations about the structure and function of the elbow. Duschl and Gitomer (1997) in research on portfolio assessment strategies coordinated curriculum, instruction, and assessment frameworks around the construction and evaluation of causal explanations for vessels floating with and without loads.

Here, then, at the level of making decisions about what counts is where we want to claim science is properly done and, subsequently, where classroom discourse and assessments should focus. When the goal of instruction is engaging students in scientific inquiry and when the organization of curriculum, instruction, and assessment models provide students with opportunities and encouragement to develop, report, evaluate, revise, and defend choices, as well as provide teachers with opportunities to capture, monitor and assess student ideas, epistemic contexts will soon dominate classroom discourse. In particular, when students are provided opportunities to develop and revise, challenge and defend a scientific claim, our observation is that wide ranging conversations in small groups and in whole class take place, a diverse reporting of ideas occurs in student reports, and, very importantly, a shift in authority from textbook and teacher to evidence and students can be seen (Jimenez-Aleixandre, et al, 1997; Penner et al, 1997; Roth, 1995) . Under such conditions, the role of the teacher becomes one of facilitation and, perhaps more importantly, one of provocateur or discovery teacher. Hammer (1997), studying his teaching in a physics class, asserts that successful teaching begins with a set of planned observations and ideas but involves unplanned divergences brought about as students engage in meaningful learning. Successful instruction, according to Hammer, is dependent on the teachers' unanticipated perceptions and insights of students' needs and meanings. Such curriculum-in the-making teaching he refers to as "discovery teaching", or what Ivic' (2001) calls "active learning". It incorporates scientific structures (concepts, principles, etc.) into "casual conversation". The idea of shifting the focus of science education to an assessment of knowledge claims is not a new one. Of particular note is the work of the Patterns of Enquiry Project (Connelly, Finegold, Clipsham, & Wahlstrom, 1977). Here the emphasis is on developing students' habits of mind, on the important role of discussion and argumentation, and on the need for enquiry to engage in an evaluation of knowledge claims. These are some of the elements of an effective pedagogy, which is a key factor influencing students' attitudes toward science, subject choice and scientific careers (Osborne, Simon &Collins, 2003). Our hypothesis is that instructional models that emphasize the symbiotic-type relationship between evidence to explanation gives rise to patterns of discourse and reasoning quite different from traditional instructional models that emphasize the relationship between evidence and concept/process learning. Thus, a distinguishing feature of classrooms that employ the kind of instructional units described above will be the argumentation that occurs and the support teachers provide to nurture and facilitate argumentation (see Simon, Osborne & Erduran, 2004).

The long term objective of our program is to better understand how to design learning environments and curriculum, instruction and assessment models that promote and facilitate student self-reflection about the status of knowledge claims, and, teacher feedback on students' argumentation strategies. The short term objective is to develop a methodological approach that teachers and researchers can employ to understand and develop the argumentation strategies employed by learners.

2.2 Argumentation - The language of science

Quality teaching involves providing quality feedback to learners (Black & William, 1998). An area of feedback that is not well understood is assisting learners with arguing from evidence to explanation, or more generally, from premises to conclusions (Driver, Newton & Osborne, 2000). According to our instructional approach, curriculum and assessment models are integrated to promote students' reflective reasoning and facilitate teachers' feedback on the same. Given that the language of science involves the evaluation and justification of knowledge claims, research on the design of ESCALATE units focuses on promoting and facilitating learners' appropriation: (1) of core science concepts, (2) strategies and criteria for reasoning about and evaluating the status of knowledge claims. The new strategies we intend to instill are argumentative.

Argumentation has three generally recognized forms: analytical, dialectical, and rhetorical (van Eemeren et al, 1996). The application of analytical arguments (e.g., formal logic) to evaluate science claims is extensive and pervasive. Case studies of scientific inquiry, however, show that the discourse of science in-the-making involves a great deal of dialectical argumentation strategies, too (Dunbar, 1995; Latour & Woolgar, 1979; Longino, 1994). Research in the sociology of science (Collins & Pinch, 1994) has also demonstrated the importance of rhetorical devices in arguing for or against the public acceptance of scientific discoveries. Cohen's (1995) position that argumentation as war is an ineffective metaphor for promoting discourse is one worth heeding. The alternative is to envision argumentation as a process that furthers inquiry and not as a process that ends inquiry. Thus, alternative metaphors for Cohen (1995) include: Argument is diplomatic negotiation, growth or adaptation, metamorphosis, brainstorming. Designing learning environments to both facilitate and promote students' argumentation, via design of the learning environment and teacher feedback, is a complex problem. The central role of argumentation in doing science is supported by both psychologists (Kuhn, 1993) and philosophers of science (Siegel,1995; Suppe, 1998) as well as science education researchers studying the discourse patterns of reasoning in science contexts (Driver, Newton & Osborne, 2000; Kelly, Chen, & Crawford, 1998; Kelly & Crawford, 1997; Lemke, 1990). Argumentation is seen as a reasoning strategy and thus also comes under the general reasoning domains of informal logic and critical thinking as well. Driver et al (2000) are correct in their assertion that we have much to learn about the dynamics of argumentation in science classrooms; particularly that which occurs among students when in groups. Although many science educators have recognized the importance of argumentation for learning, the programs proposed as well as the evaluation of these programs have been generally based on analytical forms of arguments (Kuhn, 1993) or Toulmin's model for practical arguments (Eichinger, Anderson, Palincsar & David, 1991; Pontecorvo & Girardet, 1993; Kelley, Chen, & Crawford, 1998); Zeidler, Osborne, Erduran, Simon & Monk, 2003). In these studies, emphasis is placed on the structural features of arguments (i.e., premises, initial conditions, warrants, backings) and the empirical evidence presented to or employed by learners. This approach is problematic, though, as what is fostered and evaluated is structural, somehow "arguments without argumentation" where argumentation means a process that incorporates conversational components. And indeed, research has shown that the implementation of science curricula based on argumentation is problematic if teachers are not fully engaged in the process of argumentation (de Vries, Lund & Baker, 2002; Schwarz & Glassner, 2003; Simon, Osborne & Erduran, 2003). The DUNES environment has been designed to enable students to engage in argumentative discussions through the mediation of representational tools displaying discussions and of teacher's possible control of students' participation in the discussion (Schwarz & de Groot, 2007; Schwarz & Glassner, 2007). Pilot studies have shown that the DUNES system enables:

- Co-construction of arguments

- Students' involvement in the co-construction
- Epistemological reflection on the arguments constructed (whether their truth is unquestionable, their origins, etc.).

The following dump screen exemplifies the general functioning of DUNES argumentative map generating "pad" (presently named "Digalo"):
- Participants use the shapes and arrows to discuss
- Each participant is identified by a symbol and a colour
- Shapes and links selectable
- Edit participants and shapes
- The whole discussion at a glance; full texts visible through double clicking on shapes
- Enhanced order and ease of reference.
- Replay and filtering / layering capabilities; etc.

An important additional function (invisible in the dump screen) is that the teacher can have floor control in the discussion (assigning turns or asking specific queries from students). Another important function is that DUNES provides the possibility to sustain a chat channel in parallel to the discussion. The DUNES environment leads to productive talk in several topics such as history, civic education and the resolution of moral dilemmas. The DUNES partners have noticed that, in science, e-discussion-based tools are not even when students are provided with scientific ontologies. There is a need for experimenting phenomena as a trigger for elaborating hypotheses, checking them and developing suitable explanations. DUNES is valuable when hypotheses are already articulated and backed by personal experiences. In that case, students are willing to engage in argumentative activities with discussion tools. In summary, opportunities for manipulations and observations are crucial in the learning process.

2.3 Learning through action and expression

Aiming to focus on thinking skills rather than on just knowing facts, we will follow a problem-based approach for the introduction of students to specific concepts (content). Instead of the linear, decontextualised presentation of concepts in traditional school curriculum, in problem–based approach "problems are the major vehicles for introducing important issues, and their solutions are the major carriers of curricular weight" (Schoenfeld 1994 pp 67). This means that the structure of the activities is provided by problems, goals, or issues that cut across multiple areas of traditional content (Sherin et al 2000). This idea is close to the notion of conceptual field, introduced by Vergnaud (1987) who focuses on mathematics and argues that a concept should be introduced in a set of concepts tightly related to it (instead of treating it autonomously). Another general characteristic of the activities presented here is that they are structured around open-ended problems, which allow the emergence of different approaches leaving different paths to exploration, and support – along with the pedagogical method - the development of different learning styles.

In the activities we will compose, technology is employed to support a socio-constructivist pedagogical orientation, which emphasizes "learning through action and expression" situated in social context. Under this perspective the learning process pursued in the activity plans will involve:

- exploration of concepts and ideas through experimentation, hypothesis formulation, testing,
- reification and reconstruction, establishment of connections between concepts and building on
- intuitive knowledge
- focus not only on functional (how things work) but also on structural (why they work this way)
- knowledge (the terms adopted from diSessa 2000) through model construction
- approaching ideas from varied perspectives
- systematization of ideas, abstraction, formalization and reasoning communication of idea reflection and metacognition.

These aspects of the learning process are situated in collaborative learning environments that attempt to increase students' motivation and engagement through the co-construction and investigation of concepts, which make sense and are meaningful for the students (Schoenfeld 1994). By placing emphasis on the learning process we do not mean to underestimate content. On the contrary, one of the central issues in the activity design is the balance between content pedagogy and technology (Goldenberg 1999). This means that the concepts embedded in the activities are carefully selected taking into account the special characteristics of the software as well as the pedagogical perspective adopted. In coherence with this approach we used the MachineLab as a platform were students will be engaged with problem based activities. MachineLab is a virtual reality authoring environment, where a user can combine prefabricated 3D models (Microsoft Direct3D) into dynamic real-time 3D scenes (interactive animation) using the integrated scripting support (Pascal and Logo). A physics engine (Open Dynamics Engine - rigid-body dynamics) is included and making use of it is as simple as providing two extra 3D models for each visual 3D model that is to be physics-enabled. One of the two extra models is for collision detection and the other for mass distribution (so that automatic collision response can be calculated).Ragdoll bone-based skeletal animation is supported with breakable joints, rotational stops, angular motors, skinned meshes etc., so that one can have seamless animation of skinned 3 characters (e.g. humanoids).Realistic car dynamics makes it easy to set up wheeled vehicles with working suspensions. Integrated cameraman support allows for smooth chase cameras that avoid passing through solid scenery features. Coherent sound effects (including Doppler effects), together with background music are also supported. Synchronized simulation and message exchange between many client/server machines is made available through easy to use scripting commands, and so are even more advanced features like bump-mapping, volumetric shadows, skinned shadows, mesh warping, environment reflections, true mirrors, transparency effects, particles and trails.

The design of series of activities enhancing students' participation in science lessons through the use of tools for fostering talk about science is the gist of ESCALATE.

2.4 Pedagogical framework

Based on previous work [the Kishurim project, by HUJI, the DUNES project, by all ESCALATE partners et al., and the work done by Ivic et al. (Active learning, 2002)], we take the "case" as a starting point for the design of our lessons. The case may be initiated with a story/plot, or a phenomenon in which children are asked to express their expectations, which we - as teachers and pedagogical designers imagine that will occur in pre-defined conditions. The "imaginary plot" goes from defining the issue, the goals and the path through which the various activities we plan will go and the ways we assume the students will fulfill them. While designing the case we considered the following components:

1. The specific educational goals for the particular academic subject (and/or certain blocks of materials within that subject);
2. The specific nature of the instructional material of a certain academic subject;
3. The special characteristics of the groups of students that are learning (their motivation of learning, their abilities, previous knowledge, life experience connected to the studied materials, knowledge of other academic subjects, preferences, possible resistance to learning of a particular material, etc..);
4. The actual conditions in which the learning processes occurs (in school, out of school, in the lab);
5. The specific ideas of a teacher or a team of teachers on how to perform an instruction through learning of a certain material in the planned imaginary conditions. (after Ivic 2002, p. 94)

With respect to the case design with use of technology, the designers of the activity plans outline the use of the software as a tool for:

1. model construction,
2. symbolic expression
3. orchestration – structuring of collaboration
4. multiple representation of concepts
5. synchronous and asynchronous information exchange
6. knowledge building through collecting, organization and manipulation of information
7. communication among learners

Each activity employs different combinations of the above issues according to the activity focus and objectives. The basic principle underlying the uses of technology we will present here is that in the interaction with the learning environment the initiative is left with the learner. This decision is linked to the pedagogical aspect of learner's autonomy and the support of "self determined and responsible forms of learning" on the part of the student.

These directives are very general and, when adapted to science education, they should include materials such as manipulables and measurement tools, and integrate the work in three places: the classroom, the laboratory and the museum. To this layout we will also introduce the tools and vocabulary of our argumentative and enquiry-based activities. The vocabulary includes two sets of ontologies. The first concerns components of argumentation as a formal reasoning activity (Toulminian components such as claim/conclusion, reasons/premises/hypotheses, data / warrant / backing, etc.). This ontology is in general problematic. The DUNES system enables the creation of ontologies adapted to discussions between participants: agreement, objection, explanation, elaboration, question, clarification, etc., in which the speech act is interlocutory. In other words, questioning, agreement, objection or elaboration are personalized since one participant questions/agrees/etc. another one about a specific and previous speech act.

Pilot studies with the DUNES system (Schwarz & Glassner, 2007) show that the combination of the two sets of ontologies is possible in classrooms and that this can lead to co-construction of knowledge in classes. In particular, we suggest that the use of formal reasoning components is possible in reflective activities subsequent to discussions with the DUNES system. The reason for the success of the DUNES system in construction of knowledge is that the discussion occurs in a synchronous mode, being (optionally) controlled by the teacher by means of a floor control facility. As suggested by Schwarz and Glassner, such possibilities invite to participate in social practices and collaboration. The unique blending of social, discursive and reasoning practices confers to the DUNES system outstanding capabilities. During the argumentative discussion students are not only demonstrating their arguments to others – they are acting in a social setting of stating their opinions and ideas while they are confronted with critique from their classmates. The socialization process of being able to reply, explain, and convince is a crucial part of the argumentative action. According to our experience with conducting argumentative activities in the classroom, we know that it is not enough to be aware of that situation, as it is also necessary to consider it in advance and also to train the students for gaining these specific social practices. We therefore introduced special exercises and instructions that help students and teachers in this endeavor. Such exercises are comprised, for example, from general instructions for group work, how to critique an argument, how to report and state your ideas, etc. The use of appropriate questions to facilitate argumentation can be incorporated into arguing prompts, given orally or as prompt sheets, which include questions such as, ‘What is your reason for that?’, ‘Can you think of an argument for/against your view?’ Writing frames, essentially a set of prompts to structure student writing, can also be used to help students to structure and develop their arguments during small group discussion, oral presentations, and in preparing written reports. We also helped teachers and students to evaluate arguments through analysis of exemplars. All these classroom processes were supported in training through the use of exercises and video material from the IDEAS project (Osborne, Erduran & Simon, 2006).

We used our elaborated approach for argumentative discourse also in the enquiry-based framework in which students use microworlds to perform and design their experiment, while we expect them to use the DUNES tools for planning and discussing about what is being built and how it is being done and performed. The work we refer to is the notion of constructionism, i.e., learning through constructing, experimenting and bricolage. This is a specific activity within the constructivist framework. It places argumentation within the framework of socio-constructivism, i.e., argumentation about what is being built and how it behaves. It does not soften the point of argumentation; rather, it enhances it by providing a more concrete context for argumentation [Kafai, Y., Resnick, M., Eds. (1996)]. Thus, the possibility of integrating both approaches – argumentative- and enquiry-based learning – is supported by previous research; in ESCALATE, the methods and tools associated with these approaches will find a promising opportunity for joint implementation in the field of science learning for primary school pupils.

While designing a case, teachers will be involved in a “creative teaching” which is quite different from their usual lesson preparation. The differences between preparing a case and a lesson are outlined as follows.

Differences between the written lesson-plan and a Scenario for the ALT instruction
Classical written lesson plan The ALT Scenario

1. Planned implementation of a single lesson of 45 minutes. Planning the implementation of a single lesson, as well as shorter (than one lesson) and longer (more than one lesson, and even a circle of numerous lessons) units.
2. Specifying what the teacher is going to do, the ways of implementing the lesson. The emphasis is placed on what the students are going to do. The instructional situations are being specified (to provoke different activities relevant to the academic subject) as well as students' activities.
3. Specifying the contents (WHAT should be done, the materials to be covered and the teaching methods and didactic aids to be used). Domination of HOW to initiate certain student activities and WHICH activities should be initiated. (the pedagogic interaction among students, and between the students and the teacher).
4. The focus is on implementation, the realization of the lesson plan.
1. The focus is on preparation before the lesson (designing the instructional idea which will best achieve certain goals). Planning and preparing for the lesson might take longer then the lesson itself.
5. The written plan has usually a uniform structure. (There is a risk of copying previous or other's lesson plans again and again, or strictly working according to a model). Here the strict, uniform structure, cannot exist. There might be included some information about the materials, goals, target audience etc., but the structure is dependent on the author's idea.
6. Domination of the teacher's lecturing role, and partly - of the teachers' class-organizing role. Domination of organizational (film director, designer), motivational role of the teacher, as well as on the teacher as a co-learner, partner in the pedagogic interaction.

We therefore highlighted the central role of the teacher, who becomes an inventor and designer of the case rather than a “simple” lecturer or a demonstrator. In order to achieve this goal of shifting teachers’ tasks from preparing lessons and lectures to making real inventions in science teaching activities, we developed and implemented a sound teacher’s training program and workshops to allow a large number of teachers to share our ideas and expertise and to put them in practice in their own schools. This training was carried out in close collaboration with the educational authorities in all the partners’ countries. Moreover, special efforts were devoted to the design of an online version of the training program to enable the participation of teachers from other European countries, thus substantially increasing the impact of these actions. All these efforts also helped us to create a community of science teachers. These communities enabled a fluent information flow and will facilitate arranging workshops for the purpose of training the teachers in the design of argumentative activities cases in science. The workshops were conducted, first, in the seven countries of the consortium members.

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ESCALATE: The White Book

Chapter 3: Technologies

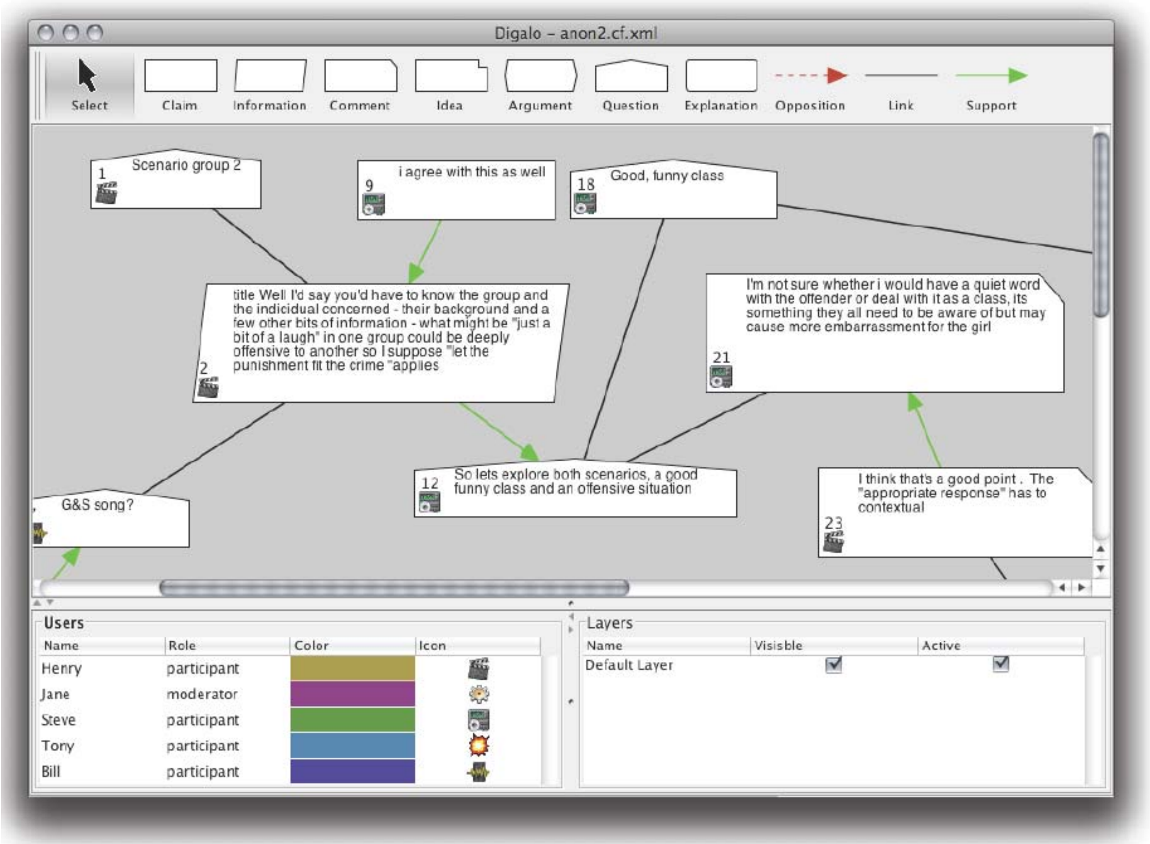
R. Drachman and C. Kynigos

Table of Contents

3.1 Digalo

3.1.1. Introduction

Digalo is a tool that was developed during the Dunes project (FP5, IST-2001-34153) for supporting argumentative learning processes (or discussions). It uses graphic means for this purpose by employing a graph structure. In a discussion, graph nodes represent discussion contributions and edges express relations between contributions. Participants discuss by adding, editing, moving and deleting nodes (*"Shapes"*) to articulate their claims, arguments, questions etc and edges (*"Links"*), which express the relation between the shapes, in a graph shared between all participants (*"Map"*).

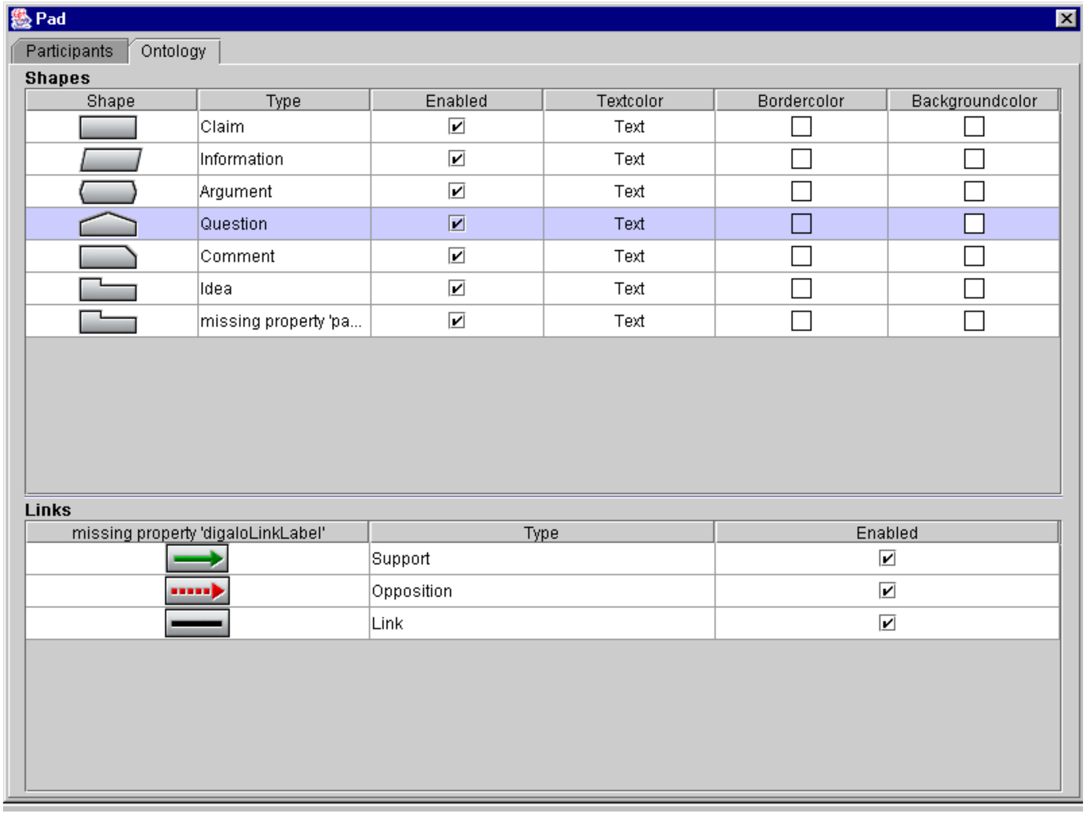


3.1.2. Digalo's Users

Digalo distinguishes between two types of users: participants and facilitators. Participants (usually students in a school environment) have limited access privileges and no access to the map's administration. Facilitators (usually teachers and/or dedicated students in a school environment) have full editing access and may change the map's settings, such as its ontology, layers, privileges, users and background image and/or grid.

3.1.3. Ontology

The ontology – represented by shapes and arrows – is aimed at facilitating the acquiring of argumentative skills. The facilitator can choose which shapes would appear in each map s/he creates. Digalo allows for up to seven contribution types (one per predefined shape).



The facilitator may change the shapes' names and the language used in the ontology. Only the facilitator is allowed to make such changes.

Each participant adds one shape (or more) and arrows/links to other's shapes in the discussion map to articulate his claims, arguments, questions etc.

3.1.4. Single- and multi-user mode

As a standalone application, Digalo works in two modes: Single-user (*"Local"*) and multi-user (*"synchronous"*) mode. In local mode, a single user may operate on a map stored in a local file. In synchronous mode, multiple users are working on a shared map, stored and coordinated through a shared Digalo server. Digalo that was developed within the Dunes project uses multiple communication techniques to overcome different technical networking obstacles such as firewalls.

3.1.5. Joining a map

By default, Digalo guides the user to its map through a three-step process on startup; however, Digalo may also be started with preconfigured server, map and/or user. If all needed parameters are given, Digalo starts directly into the running discussion.

3.1.6. Floor Control

Digalo employed an access mode called *Floor Control*. This feature has two modes from which the facilitator can choose before or during the session:

- FC Activated: only one participant (the floor owner) can work on the board (add shapes and edit the text in a shape) at a given time, while all other participants have to wait for their time slot. The first to request FC will receive it immediately, and others will enter a line for receiving FC. The facilitator (teacher or a student assigned by the teacher to facilitate the discussion) can manage the line (decide whether one student will receive FC before others, or vice versa) and take the FC from a student if s/he thinks this is necessary.
- FC Deactivated: all participants can work simultaneously, without taking turns.

3.1.7. Layers

Digalo allows the facilitator to define multiple layers. Each contribution is assigned to one specific layer. Layer visibility may be turned on and off individually to simplify large discussions or to distinguish discussion phases. Each user may configure layer visibility individually. A bar at the bottom of the main screen may be expanded and collapsed for this purpose.

3.1.8. Map canvas, grid and background image

In Digalo, the map background is a virtual empty area of theoretically unlimited size, expanding and shrinking as needed Instead of a plain color, facilitators may set a regular grid or an arbitrary image as map background, for example to illustrate a discussion topic or to provide a spatial structure.

Each participant in Digalo has a distinctive color and an icon that helps identify his/her contributions on the board.

3.1.9. Applications of Digalo

The Digalo tool can be adapted for use in education and training programmes by "translating” existing courses into the Dunes/Digalo format or by providing the institutions with "cases" which are background instructions and material for discussion and related guidelines for Dunes applications. These cases can be useful for teachers in moderated argumentative activities. The implementation of Dunes-based courses or training sessions can be developed in schools, universities, companies, by governments, etc. The Group can also offer teacher-training in Dunes-related (or other argumentation-based) teaching activities.

3.2 Microworlds

3.2.1. What is a Microworld?

'Educational Microworld' is a term with a long history behind it. It was originally borrowed by Seymour Papert from artificial intelligence (A.I.). Its meaning evolved within the mathematics and science education community. Papert described it as a self-contained world where students can "learn to transfer habits of exploration from their personal lives to the formal domain of scientific construction" (1980, p. 177).

Micro-worlds are computational environments embedding a coherent set of mathematical and/or scientific concepts and relations designed so that with an appropriate set of tasks and pedagogy, students can engage in exploration and construction activity rich in the generation of meaning. The first example of a microworld was 'Turtle Geometry' within the Logo programming language which generated a bulk of research on the construction of children's geometrical meanings (Laborde et al, 2006). Later research however, involved learning with the use of micro-worlds embedding a much narrower set of mathematical and scientific concepts, escorted by more focused theories on learning and pedagogy (Noss & Hoyles 1996, Edwards 1995, Clements & Sarama 1997, Sarama & Clements 2002).

3.2.2. The evolution of perceptions of microworlds

In the early days, microworlds were seen as strictly programmable environments and their main characteristic was the ability to construct graphical models using a programming language. The semantics and rules of the language as well as the graphical representations were integrated with the concepts and relations of the domain characterizing the microworld. The key features of the students' activities enabled with such media were the ability to make constructions and change and extend the rules and relationships of the microworld itself. The highly editable nature of these media and their executable representations providing immediate and epistemologically succinct feedback (they can be characterized as conceptual mirrors) enabled exploration and bricolage and the kind of learning which took place was characterized by Papert and his team as a special kind of constructivist learning which they termed 'constructionism' (Kafai & Resnick, 1996). Seen in a wider context, microworlds were examples of the idea of 'deep structural access' (diSessa 2000, Kynigos 2004, Kynigos 1995) to technologies for non-technical people, allowing for creativity, customization and personal construction of technological tools. This idea was used as an argument for the use of technologies to facilitate the growth of a technological culture rather than to inhibit creativity and expressivity with technologies.

In the field of education, with the advent of new interface technologies and the broadening of the domains over which microworlds were designed including that of science, programmability and constructionism faded in favor of dynamic manipulation of representations and higher quality graphical and iconic representations offered by multimedia and enabled by a suite of authoring systems. In science the microworld rhetoric quickly gave place to that concerning simulations. One key issue was the primary importance given to the accuracy and detail of the behaviors and relationships between objects in the respective simulation. This was based on epistemologies primarily focused on the phenomenological nature of the domain rather than on meaning construction.

Another issue was the extent to which the simulation represented objects as realistically as possible or provided an abstraction from the objects' shape and form (as in Interactive Physics). A third was the ways in which the simulation was mediated to students and the way they themselves perceived it as a real infallible phenomenon in itself or as a human-made simulation consisting of an inevitable approximation of the objects and the simulated phenomena.

In mathematics on the other hand, the problem lies with the epistemological nature of the domain itself. Mathematics can be seen as an abstract domain of human thought, its objects being axioms, relations and mathematical proof. On the other hand it can also be seen as an applied science explaining various phenomena (economic, scientific, geometric, navigational, etc). Microworlds were seen to make mathematical representations useable and learnable and thus gave rise to some questioning about the learnability of traditional mathematical representations, such as formalization, providing alternative representations designed to facilitate meaning generation (Hoyles et al, 2002).

In both cases of science and mathematics education, however, programmability and constructionism re-appeared recently with the advent of technologies allowing for programmable simulation-multimedia style tools such as E-slate microworlds (Kynigos, 2004, Penner, 2001), Boxer microworlds (diSessa, 1997), Micoworlds Pro and Imagine Logo. These kinds of microworld constitute simulations which can be used at different levels by teachers and students alike. They can be used as phenomenologicaly authentic simulations providing iconic interfaces to change parameters within worlds with unchangeable rules and at the same time, as questionable worlds where rules can be changed and tampered with to generate inquiry of what it would be like if they were different.

3.2.3. Microworlds as tools for pedagogical innovation in schools

The microworld idea was first coined in the late seventies by Papert. In his argumentation he presented this kind of technology as a medium to challenge and bring about re-thinking of the educational paradigm of schooling and the epistemological approach of content domains such as mathematics. This rationale came about in the historical context of some bold attempts for curricular changes in the states based on the problem-solving movement which focused on problem-solving methods rather than the understanding of mathematical concepts in themselves. Microworlds were seen as the ideal technological boost to the movement. Inevitably, they thus became victims of the educational innovation pendulum (Agalianos 1997, Noss 1992). They also became victims of the early stage in which they were created with respect to the spread of technology in the culture (Papert, 2002). Technologies were very hard to access, machines were slow and non-dependable, the internet had not arrived and people were not widely using digital technologies for something else. However, microworlds continued to be designed and used in design research initiatives providing evidence that when placed in the role of tools within a carefully designed and supported educational environment, they could greatly facilitate the generation of mathematical and scientific meanings in students. Furthermore, they appeared in contexts different to the one they originated from in countries such as Mexico, Kosta Rica, Greece and others (Blikstein & Cavallo 2002, Kynigos 2002). Recently there seems to be growing indication of a comeback of microworlds in a different role, that of digital artifacts for argumentation and inquiry learning in a digitally rich culture, which by itself will provide an external challenge to the schooling paradigm (Papert, 2002).

3.2.3.1. Microworlds as tools for inquiry learning in ESCALATE

In the ESCALATE project we used the term 'microworlds' to describe an explorable and malleable digital environment characterized by an embedded knowledge domain, acting as a coherent world, inside which a student can explore alternatives, test hypotheses, and discover facts that are true for this world. The basic characteristic of a Microworld is thus that it is designed as a rule-governed environment which is accessible for manipulation and exploration by the learner. The kind of manipulation may vary according to the subject domain and the decisions of the designer. We developed a suite of nine microworlds based on the collaboration between the project partners and the ETL-Talent teams which have a history of development of authoring tools for microworld construction and their use for design, development and use of specific microworld tools. The technological affordances which were used and emphasized in the project were such so that a microworld:

- Constitutes an exploration space
- Mediates between informal and formal
- Provides executable representations
- Offers dynamic manipulation
- Evokes interplay between private and public expression
- Generates interdependent representations
- Allows deep structural access to its functionality by means of a programming language

Microworlds constructed in this way provide powerful sites for inquiry based learning. They offer to the student opportunities for construction, exploration, observation, reflection and collaboration (see for instance, Noss & Hoyles, 1996). Although there seems to be a distinction between programmable-constructionist and simulation based microworlds, the ETL-Talent group proposed an integrated approach providing the first type of affordances to simulation-like tools. The emphasis was to design for the potential for users to change the rules and the laws that dominate the microworlds themselves. In that way, when the didactical design and time constraints allow, students can question the rules and the concepts underlying those rules e.g. by asking 'what if' questions and being able to test them.

As diSessa describes microworlds, they are

> *"a type of computational document aimed at embedding important ideas in a form that students can readily explore. The best microworlds have an easy-to-understand set of operations that students can use to engage tasks of value to them, and in doing so, they come to understanding powerful underlying principles." (diSessa, 2000, p.47)*

In the ESCALATE project, we have distinguished between the design of microworlds and their use in learning environments. This kind of distinction was first suggested by Edwards who used the terms '*structural and the functional view*' to express it (Edwards, 1995). The former is the point of view of the designer and focuses on how the microworld is constructed and the latter is the point of view of the user and focuses on the way the microworld is used. Thus, form a structural point of view the microworld is consisted by a set of computational objects representing entities (usually mathematical or scientific) of the domain which is modeled by the microworld, is equipped with various representations of the properties and the behavior of the entities, mainly visual or graphical and includes a set of activities with the entities, which are designed in order to reach predefined educational goals. Finally the microworld is designed so that it can be expandable and permits the combination of existing objects and operations in order to construct more complex ones.

3.2.3.2. Microworlds for scientific and mathematical thinking with

When, on the other hand, we consider how microworlds are actually used and function as learning environments, we may describe them as a digital environment where the learner

- can manipulate the objects in order to discover their properties and understand the laws which dominate their behavior,
- can make hypotheses and use the feedback from the environment to test them, in order to correct his or her own ideas about the domain modeled by tinkering with and debugging the microworld and
- can use the microworld environment in order to investigate specific problems.

Within learning environments based on the use of microworlds the learner is not told about a mathematical or scientific concept; on the contrary he/she is supposed to generate meanings about the concept through interaction with the microworld by playing a game or solving a problem.

The particular focus in the project was on designing microworlds which would be used as expressive digital media, within situations providing rich opportunity for the generation of meanings through discussion and reflection amongst students, as they collaboratively explore with the microworlds. We thus drew on a theory of media use from the field of cognitive ergonomics (Rabardel, 2001) which has been found pertinent in the field of mathematics education. Rabardel extended Vygotsky's work on semiotic mediation, perceiving the use of digital media as a social mediation with cultural artifacts, stressing that the way and purpose a medium is used by an individual warrants rigorous attention. He thus distinguished between an artifact (i.e. the computational object as constructed by humans) and the set of meanings constructed and mediated through the use of an artifact, which he called 'an instrument' (Guin and Trouche, 1999). In that sense, artifacts that allow and support the *generation* of instruments are particularly interesting in educational processes based on the experiential learning paradigm. In mathematics and science education it may make much more sense to conceive of digital artifacts as *objects for instrumentation*, i.e. objects with which a variety of instruments are going to be created. Seen from this perspective, the didactical design of such objects would be essentially congruent with the argumentation paradigm in distinction to conventional educational material which is in most cases designed to play the role of unquestioned authentic pieces of information or directions for activity leading to these. They provide however, a special focused case within this paradigm where argumentation is focused on the specific process of inquiry and construction by means of instrumentation of digital artifacts.

3.2.3.3. The notion of half-baked microworlds

The idea of an object explicitly designed to invite instrumentation leading to inquiry learning was termed by Kynigos as a 'half-baked microworld' (Kynigos, 2002). Half baked microworlds are pieces of software explicitly designed so that the learners would want to build on them, change them or de-compose parts of them in order to construct an artifact for themselves or one designed for instrumentation by others. They are meant to operate as starting points, as idea generators and as resources for building or de-composing pieces of software. This constructionist activity is seen as part of inquiry and argumentation leading to the generation of mathematical and scientific meaning.
At the same time, half baked microworlds can be designed for teachers to engage in pedagogical or epistemological reflection as they de-construct or re-construct the microworlds in a context of designing tools for students. Half baked microworlds operate like diSessa's toolsets (diSessa, 1997) in that they are not built and presented as readymade environments to be understood by the teachers and then used by students. Instead, the point is to change and customize them and thus to gain ownership of the techniques and the ideas behind microworld construction as outlined earlier

3.2.3.4. Microworld design as an integral part of case design

In the ESCALATE project, the partners engaged in the collaborative design of microworlds to be used as constructionist tools for inquiry and argumentation. This is very hard to do, especially amongst actors with different expertise working in a variety of contexts.

Furthermore, implementing microworlds in formal or non formal educational environments is not a simple task. The teacher must be able to adopt both the role of the learner and the role of the facilitator, to work with small groups and to have communication abilities at a high level.

The open-ended nature of the microworlds makes it difficult to integrate them into educational systems. The use of microworlds is more time consuming than the typical educational procedures taking place in classroom. Inquiry based learning, which is mainly promoted with the microworlds, impedes inexperienced teachers from setting distinct and clear tasks for their teaching. If the microworld or the activity is not well designed, it is possible that the students will lose their interest and get bored, situation that leads to discipline and misconduct problems in the classroom.

Thus, if using microworlds in educational practice is a composite task, the designing of them is a more complicated and demanding procedure. It requires a synthesis of expertise: in computer science; in specific domain teaching and learning theory and in the method of integration and support of the use of the microworlds in real school settings.

The composite expertise needed for the development of microworlds can be found by the collaboration of people coming from different cultures. For example, a programmer could collaborate with an educator in order to construct a microworld in the domain of expertise of the educator.

This collaboration is not certain that it will be successful. It might be proven that the two experts cannot understand each other. They don't focus on the same aspects of the microworld, they are not interested in the same things and it is possible that they will discover that they cannot communicate since their languages are incommensurable. Finally, they will face the problem of hierarchy: who has the dominant role? Should the developer do his/her best to accomplish the design of the educator or, on the contrary, the educator should obey to the constraints posed by the developer and change his/her initial design?

Collaboration between experts for the development of microworlds can be successful if each one of them has gained some insight into the work of the other. In this way pathways for communication will be developed and a common language will be shaped. In this way the experts will be transformed to *hybrid actors* (Kynigos, 2002).

The second case for microworlds' development is that a single person, usually an educator, has gained the expertise of manipulating an educational software platform and constructs the microworlds according to his/her didactical addenda. Many educational software like e-Slate and MachineLab, have been developed in such a way to allow the independence of educators from the developers in order to produce new microworlds.

In the ESCALATE project we used both procedures for the development of the 9 microworlds of the project. As we will see in the next paragraph, three of them were developed by a single person who had both the educator's and the developer's expertise, while the other 6 were developed with the collaboration between developers and educators.

3.2.3.5. The educational software used in the ESCALATE project

The microworlds that were developed during the ESCALATE project were based on two platforms: e-Slate and MachineLab. The main characteristics of the platforms are presented below.

3.2.3.6. The e-Slate platform

E-Slate is an exploratory learning environment. It provides a workbench for creating highly dynamic software with rich functionality by non-programmers. Educational activity ideas can be turned into software with minimal authoring effort in the form of interactive Microworlds, which contain specially designed educational components. E-Slate components are provided as a kit of pre-fabricated, interoperable computational objects, encompassing domain-specific knowledge and playing the role of high-level building blocks in the creative hands of "end users".
With e-Slate it is easy to construct software Microworlds by plugging the proper components in various configurations. The behavior of the Microworlds can be programmed in a Logo-based scripting language. In this way non experts can become software developers without being involved with data-models, algorithms, and low-level programming. Software construction resembles assembling a "kit" rather than "writing a program.

3.2.3.7. The MachineLab platform

Machine-Lab is an authoring environment and test-bed for the creation and exploration of interactive virtual reality scenes (VR-microworlds). The representational infrastructure provided by Machine-Lab concerns controlling and measuring the behaviors of objects and entities in virtual environments simulating real three-dimensional phenomena and spaces. The design of MachineLab includes various kinds of representation of three dimensional worlds and objects enhanced by interactive and dynamic display affordances for the user.

MachineLab is implemented over the 3impact game engine (www.3impact.com) which wraps the stunning 3D graphics of the Direct3D engine and the distributed/multi-user capabilities of the DirectPlay engine, together with a 3D sound engine and the Open Dynamics Engine (www.ode.org), which is a Rigid-Body Simulation engine with realistic physics support for 'collidable' objects and articulated bodies (rag-dolls / humanoids).

Within the MachineLab user is able to design microworlds providing multiple 3d external representations, analogical to some aspect of the physical world, within which students could dynamically control the vectorial representation of magnitudes through manipulation of keyboard buttons or use Logo-programming so as to control the simulation, to change the laws of motion or the behavior of the moving agents. The platform offers the possibility of multiple observations from different point of reference. The user may adjust a virtual camera on any object, moving or still, and observe the phenomena using multiple system of reference.

3.2.4. The "Microworlds" developed in ESCALATE project

3.2.4.1. Introduction

For the needs of ESCALATE project were transformed or developed 9 digital microworlds. The 6 of them were developed with e-Slate and the 3 of them with MachineLab. Three of the microworlds were not developed from scratch but were transformed from previous versions developed for other educational scenarios.

Both platforms allow non experts in ITC to create powerful microworlds. This doesn't mean that someone who has no experience in programming with Logo and who has never before worked with this kind of platforms could create easily complicated microworlds, related to any scenario he or she might think.

That's why for the needs of the project we have chosen the model of collaboration of people with different expertise in order to develop the microworlds. The teachers developed the scenario end tried to describe the microworld from a functional point of view. In other words they described what they wanted the students do with the microworld and how they wanted them to interact with the objects and the tools. Afterwards the ETL group was analyzing the laws underlying the environment in a way that it was possible to the developers to understand them and transcribe them to Logo script. Finally the developers were constructing the microworld trying to adapt it to the description of the teachers.

Of course this procedure was not simple and the result didn't come out easily. Many corrections had to be made so that the microworlds fit the most to the initial design, in some cases features planned by the teachers could not be materialized due to the constraints of the platforms etc. In cases where the educators and the developers had not collaborated in the past, the mediation of the members of ETL has been proven very helpful. They were "translating' the description of the educator to a "language" familiar to the developer and they could explain to the educators what the developers were describing as technical constraint or technical problems. This experience proves that a common language is necessary in order to have a fruitful collaboration between educators and developers.

For a complete functional and structural description of each microworld we will use a template with specific fields to be completed. Here follow some elucidations about the fields of the template.

3.2.4.2. Template for the description of Microworlds developed for the project

a. Title

b. Represented Phenomenon

Here, a short description of the phenomenon or the situation represented with the microworld is presented. Besides the scenario, the description includes also the scientific laws of the relative to the phenomenon domain

c. Level of abstraction

At this point the level of abstraction used to represent the participating entities to the phenomenon is described. If, for example, a moving vehicle is represented as a ball, the representation is characterized **abstract**, but if the vehicle is represented as a car whose wheels are spinning, the representation is characterized **realistic**.

c. Concepts inquired

Here the concepts that are directly involved to the inquiry with the microworld are enumerated.

d. User Interface

d.1. Description of the scene

It consists of a short description of the features of the scene where the phenomena take place and run.

d.2 Manipulation

The tools which are at the disposal of the user in order to control the represented entities and the parameters of the microworld are described. Also, it is included a description of the kind of manipulation that the user is allowed to have on the microworld

e. Programmability

The question here is whether the user is allowed/encouraged to interfere to the software code in order to transform it and change the rules and the hidden (physical) laws that govern the microworld, as well as the relationships between the parameters and the magnitudes.

f. Feedback from the computer

f.1 When changing the parameters

Here the results which are observed by the user on the computer screen, when she/he changes a certain parameter of the microworld are described.

f.2 As result from the experimentation

The possible results of the experimentation are described in relation to their complexity and multiformity. Thus there may be outcomes which are complex, such as the trajectory of a moving body, or other which have the binary form of true/false, yes/no etc.

g. Mathetic procedure

The term Mathetic is used, after S. Papert's proposition, as "the art of learning" (Papert, 1996, p.10), or more explicitly, as the set of "guiding principles that govern learning" (Papert, 1980 p.52). Thus, at this point, a distinction is made depending on the way that the user is expected to interact with the concepts under investigation. Is she/he supposed to understand them by using them to explain and interpret the phenomena represented at the microworld, or is he/she going to answer questions about them and try to find the right answers? The former includes cases where the concepts are **to be understood** and the latter cases where the concepts are **to be questioned**.

h. Didactical structure

The didactical structure of the microworld depends upon its characteristics. The two edges here extend from the structure of a simulation, where the microworld represents, in a very precise way, a specific phenomenon, to the structure of a constructionist microworld, which is used by the students in order to construct an artifact or create a specific situation.

i. Type of representations used

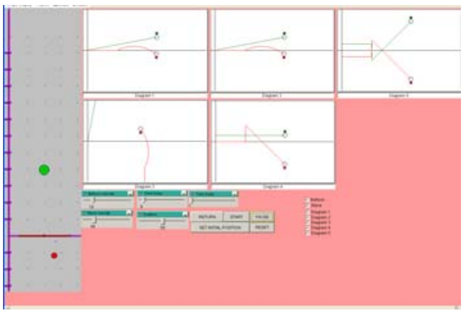
At this point the representations used in the microworld are described. It is certain that phenomenological representations will be used to all microworlds. Thus, the description will be focused on whether they are combined with mathematical representations or not (graphs, histograms etc.)

j. Procedure of development

The development of the big majority of microworlds involved educators and programmers to a big variety of roles and with a big variety of procedures. At this point the way that every microworld was developed is described (the persons involved, the type of collaboration, the type of communication etc.)

3.3 Hit the Balloon

a. Represented Phenomenon



The subject domain of this microworld is Kinematics and especially the normal and the accelerated motion of bodies in the field of gravity. The scenario is that a balloon takes off the ground, moving upwards with constant velocity; after some time, an object is thrown vertically upwards, in order to reach the balloon. The goal for the user is to examine the conditions under which the object meets the balloon and predict what will happen when the parameters of the problem are changing

b. Level of abstraction

The representation of the phenomenon is very abstract. Both the balloon and the ejected object are represented as balls, there is no representation of the landscape where the phenomenon is supposed to take place, nor for the hit of the balloon by the ejected object.

c. Concepts inquired

The inquiry is about the concepts of velocity, relative velocity, acceleration, position, distance, displacement and meeting of two bodies.

d. User Interface

d.1. Description of the scene

As it was said before the scene of the phenomenon is not represented and it is just a grey area, so that the two colored balls representing the balloon and the object can be easily distinguished. Next to the area where the bodies are moving, there is the space for the graphical representations and under it the space for the manipulation tools of the microworld.

d.2 Manipulation

The user may adjust all the possible parameters of the balloon’s and the body’s motion with sliders. He/she controls the start and the pause of the representation with buttons. Also, with the use of buttons, the user can adjust the initial positions and clear all the data in order to restart the simulation. Finally the user, with the use of 6 check boxes, controls how many graphs will appear to the screen and whether both the balloon and the ejected object will participate to the simulation.

e. Programmability

The Logo script that controls the behavior of the 2 bodies and drives the “turtles” who design the graphs is available to the user. The case is not designed by default to encourage reprogramming by the user, but if the teacher who will use the microworld wants, he/she may pose questions that will induce the students to moderate the laws and the relations of the microworld by changing the software script.

f. Feedback from the computer

f.1 When changing the parameters

When changing the parameters the user observes immediate response on the screen. The bodies and the graphs appear or disappear, the initial position of the two bodies changes, the delay of the taking off for the ejected object and the initial velocities diminish or increase.

f.2 As result from the experimentation

The outcome from the experimentation is the trajectory of both bodies and the graphical representations of the oscillation of the magnitudes involved to the phenomenon.

g. Mathetic procedure

The inquired concepts are to **be understood** through observation of the phenomenon and interpretation of the graphical representations.

h. Didactical structure

The microworld has the characteristics of a simulation in the sense that it is dominated by the exact laws of kinematics and the representations are precise and in accordance with the real world experience. At the same moment it has the characteristics of a constructionist microworld in the sense that the user may define the behavior of the moving bodies, by moderating (via scripting) the underlying rules of the microworld.

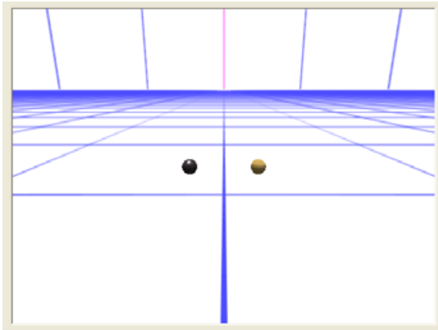
i. Type of representations used

The phenomenological representations of the motion of the two bodies are combined with mathematical graphical representations of the most magnitudes involved to the motion (velocity, position displacement, relative velocity). All the graphs are calculated vs time.

j. Procedure of development

The microworld was developed with the very close collaboration of a Physics teacher, not very experienced in the use of microworlds as educational tools and a developer with big experience in developing microworlds with e-Slate platform. The developer left to the teacher the initiative about the interface and the tools of the microworld, but the decisions he took about the structure of the script influenced the final result at pedagogical level. For example, because of the developer’s decision that the minimum time interval representing the notion of “moment,” would not be infinitesimal, instead it would be a very small discernible time slot, the students must use approximations in order to understand the way the bodies are moving. This situation obscures their understanding of the phenomenon, but on the other hand helps them understand the scientific practice when we are studying a phenomenon, since scientists in the lab work always with approximations.

3.4 Mysterious Forces



a. Represented Phenomenon

The subject domain of this microworld is Dynamics and especially the behavior of two bodies when they interact through a central internal force or when external force is exerted to them.

b. Level of abstraction

The representation of the phenomenon is very abstract. The two bodies are represented as balls without any special characteristics and the scene of the phenomenon is represented as a Euclidean 3d space.

c. Concepts inquired

The inquiry is about the concepts of force, mass, impulse, impetus, interaction, inertia.

d. User Interface

d.1. Description of the scene

As it was said before the scene is just a Euclidean space equipped with a 3d system of coordinates. There are no control tools in the disposal of the user.

d.2 Manipulation

The user may adjust the mass of the two bodies and their initial distance. Also they may set the measure of the forces exerted to the bodies, in two different ways: they can set the numerical value for its force (positive if the direction is to the right and negative if the direction is to the left) or they can set the value for one force and determine its ratio to the other (positive ratio means that the two forces have the same direction and negative that the directions are opposite.)

e. Programmability

The Logo script that controls the behavior of the 2 bodies is available to the user. Actually it is only by interfering to the script that the user may moderate the values for the masses, the forces and the initial distance of the two bodies. In order to facilitate the implementation of the microworld in actual school classroom conditions, we "extracted" from the main script some code lines with the variables that must be determined by the user. At a higher level these lines can be deleted and in this way the user will be induced to get access to the deep structure of the script and invent how the physical laws are "translated" to Logo commands.

f. Feedback from the computer

f.1 When changing the parameters

When changing the parameters the user does not observe any change, except from the alteration of the bodies' behavior.

f.2 As result from the experimentation

The outcome from the experimentation is the behavior of the two bodies. The bodies move in a different way, according to the measure of their mass and the exerted force.

g. Mathetic procedure

The inquired concepts are to **be understood** through observation of the phenomenon and interrelation of the bodies' behavior to the measure of the parameters.

h. Didactical structure

The microworld has the characteristics of a simulation in the sense that the bodies' behavior in the Machine Lab platform follows in a very precise way Newtonian physics. On the other hand the students must create the situation that they will study, and in this sense the microworld in sited in the constructionism agenda.

i. Type of representations used

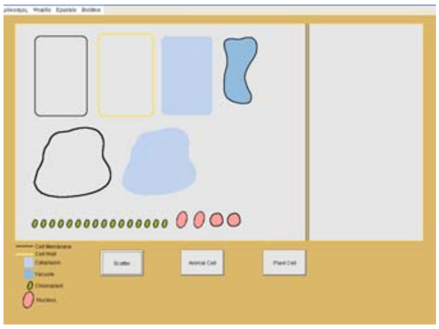
The microworlds uses only phenomenological representations.

j. Procedure of development

The microworld was developed after the collaboration of a Physics teacher, quite experienced in the use of microworlds as educational tools and a developer with big experience in developing microworlds. In this case, instead of having an initial design of the microworld by the teacher, it was the developer who had the initiative and who constructed a first draft of the microworld. This first draft gave birth to the educational scenario developed by the teacher and finally to the final version of the microworld.
The whole procedure proves that exploratory software helps both the communities of educators and of developers to cultivate competencies that are not characteristic of their own domain of expertise. Not only an educator can be transformed to a developer and produce a complex digital microworld, but also a developer can gain the experience to produce pieces of software extremely interesting from an educational point of view.

3.5 Animal and Plant Cell

a. Represented Phenomenon



The subject domain of this microworld is biology and especially the structure of animal and plant cell.

b. Level of abstraction

The representation of the phenomenon is abstract. Each part of the cells is represented with a corresponding figure, whose shape and texture has a small relation to reality.

c. Concepts inquired

The inquiry is about the concepts of animal and plant cell, membrane, cytoplasm, vacuole, chloroplast, cell nucleus.

d. User Interface

d.1. Description of the scene

The scene is divided in two areas. At the left there are the parts of animal and plant cells and at the right the user composes the representation of a cell by dragging the parts from the left area. Under the two areas there is the index showing the correspondence between the figures and the cell parts and the buttons for the manipulation.

d.2 Manipulation

The user manipulates the entities dynamically by dragging and dropping the cells' parts with the computer mouse. He/she may clear the experimentation scene with a button and may use two more buttons to observe the structure of plant cell and an animal cell and compare them with his/her own construction.

e. Programmability

The microworld is not programmable.

f. Feedback from the computer

f.1 When changing the parameters

The user does not change any parameters. When she/he transfer a part of a cell from the left area to the area of experimentation, the part leaves the place where it was stored and becomes part of the under construction cell at the right area. .

f.2 As result from the experimentation

The outcome from the experimentation is the representation of the animal or the plant cell, which the user may reveal using the two relative buttons.

g. Mathetic procedure

The inquired concepts are to **be questioned** since the user after having constructed the artifact that she/he had designed, she/he compares it with the correct model of the cell type.

h. Didactical structure

The microworld has the characteristics of the constructionist microworld, since the users are expected to construct an artifact with a structure defined by them and not predefined by the software.

i. Type of representations used

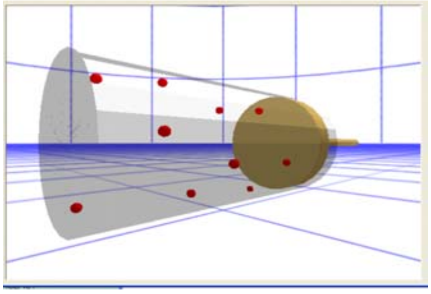
The microworld uses only phenomenological representations.

j. Procedure of development

The microworld was developed after the collaboration of an educator and a developer. The interface and the features of the microworld were described by the educator and the developer followed the instructions to construct the microworld. There were some communication difficulties, since they had not worked together again and the developer was not familiarized at all with the subject of Biology. Despite that, they managed to understand each other with the interference of the members of the ETL, team who had worked with the developer many times and who could better understand the description of the educator.

3.6 The Air Pressure

a. Represented Phenomenon



The subject domain of this microworld is the gases' laws and the atomic theory. Some molecules of an ideal gas are in a chamber with transparent walls; the volume of the chamber alters and, as a consequence, the gas pressure varies.

b. Level of abstraction

The representation is quit realistic since the molecules of the ideal gas are represented as elastic balls and the shape and texture of the chamber and the piston resemble to their real characteristics. All the representations are 3d and this adds to their realistic character.

c. Concepts inquired

The inquiry is about the concepts of pressure, atomic velocity, ideal gas, atomic collisions.

d. User Interface

d.1. Description of the scene

The scene of the microworld is the representation of a transparent chamber where the gas atoms are free to move in a chaotic way. The alterations to the volume of the chamber are obtained with a moving piston.

d.2 Manipulation

The user manipulates dynamically the microworld by moving the piston with the left and right arrows. Also, she/he may change the point of view for the observation with the up and down arrows. Finally, the user may change the number of molecules and their maximum velocity by setting the values he/she wants to the relevant lines of the Logo script.

e. Programmability

The microworld is not programmable with the exception of the adjustment for the number of molecules and for the maximum velocity, which was described previously.

f. Feedback from the computer

f.1 When changing the parameters

When changing the number of molecules the number of balls in the chamber becomes immediately equal to the value set by the user. Equally, by changing the value of the maximum velocity, the molecules adjust their velocities in order to fit with the value set. These adjustments can be done only at the beginning of the experimentation.
The alterations of the volume with the L and R buttons can take place while the experimentation is running and their immediate result is the displacement of the piston. At the same moment the velocities of the molecules change dynamically, in order to be in accordance with the new gas pressure.

f.2 As result from the experimentation

The outcome of the experimentation with the microworld is the observed behavior of the molecules in the chamber.

g. Mathetic procedure

The inquired concepts are to **be understood** since the user is supposed to repeat the experiment many times with different values for the number of molecules and the maximum velocity and understand the correlations between volume, pressure and molecules' kinetic energy.

h. Didactical structure

The microworld has the characteristics of a simulation, since the users are not expected to construct something but, instead, they are expected to observe a phenomenon represented in a realistic way.

i. Type of representations used

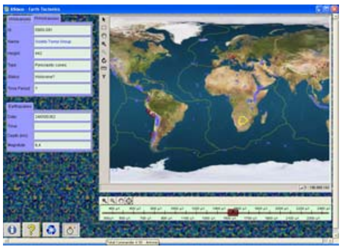
The microworld uses only phenomenological representations.

j. Procedure of development

The construction of the microworld was based on the description made by an educator and the clarifications made by the ETL team so that the developer would understand the laws underlying the environment. There were certain constraints due to the potentialities of the platform used for the development (MachineLab). First of all we could not exceed a certain number of molecules inside the gas chamber. This constrain can be used by the teacher since in the real world as well there is a constraint concerning the number of molecules for a gas that is supposed to be ideal. The second constrain is that after a long period of time the molecules start to "escape" from the chamber. This bag can also be used by the educator who implements the microworld, since this is the way that gases behave in the real world: phenomenon of gas diffusion.

3.7 Earthquakes

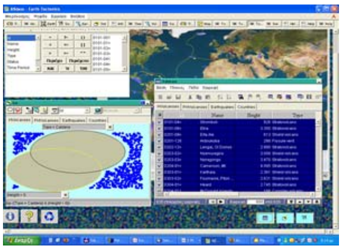
a. Represented Phenomenon



The subject domain of this microworld is the tectonic plates on the surface of the earth and their relation with earthquakes and volcanoes.
In the microworld are presented the known volcanoes and the earthquakes that have happened, from the ancient era till nowadays.

b. Level of abstraction

The representation is abstract. Specific symbols, like colored triangles and circles, are used to represent volcanoes and earthquakes on the map, while in the query view they are represented with Venn's diagrams. The magnitudes of the earthquakes are represented on the map with the measure of the sign which is used to represent the position of the earthquake's epicenter.



c. Concepts inquired

Concepts that are directly involved to the inquiry with the microworld are the relationship between the earth tectonics and the volcanoes and earthquakes, the categories of volcanoes and the categories of earthquakes.

d. User Interface

d.1 Description of the scene

Earth tectonics microworld has two views, each one supporting different sets of tools and functions. In the timeline view, pupils may use the time-machine to view the global seismic and volcanic activity, as it was recorded in historical times until now. In the query-set view, pupils may conduct various statistical studies and measurements with the data for volcanoes and earthquakes by using the Set, Query and Database components.

d.2 Manipulation

By manipulating the time cursor of the timeline tool, pupils can observe on the world map the places where an earthquake happened or a volcano erupted, at any period in the past.
Also students can structure and edit queries with the Query component and see the relative to the query data which are recorded to the data base being projected to the map and being presented organized in Venn's diagrams.

e. Programmability

It is not in the aims of the microworld to involve pupils in programming.

f. Feedback from the computer

f.1 When changing the parameters

At any time, the Map displays only volcano eruptions and earthquakes that happened into the chosen time period. If the time frame is suitably chosen, the pattern of seismic spatial distribution begins to show up and it may easily be observed that this pattern coincides with that of the distribution of volcanic activity, and eventually with the map of the tectonic plates (the corresponding map layers can be rendered visible or hidden by using the Map Legend buttons).

f.2 As result from the experimentation

The inquiry procedure in this microworld is evolving by constructing simple or complex queries in formal logical expression, which are combinations of the database fields and logical operators. The result when the query is executed is presented in multiple representations as described above.

g. Mathetic procedure

The inquired concepts are to be questioned and the pupils using tools and data from the microworld are trying to answer the questions.

h. Didactical structure

The main characteristic of the microworld is the potentiality, given to the pupils, to manipulate a large amount of data and the multiple representations of the specific information that they acquire through the queries that they construct.

i. Type of representations used

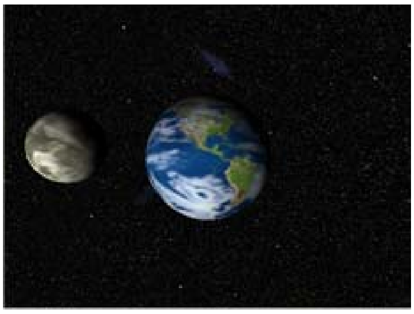
Besides the phenomenological representations for the map and the events on it (earthquake and volcanic eruptions) the microworld uses mathematical representations as well: data about the specific volcano or earthquake are presented in a matrix form and the results of the executed query are organized and presented with Venn's diagrams.

k. Procedure of development

The microworld was developed by an ITC expert with a great personal interest in geography. Although he had not an educator's background he has been collaborating for a long period with ETL team and this gave him the expertise to design and develop microworlds. For the needs of ESCALATE project the microworld was translated in English and some wrong data and problems in the structure were fixed.

3.8 Sun Earth and Moon

a. Represented Phenomena



The microworld "Sun, Earth and Moon" is a simulation of the movements of these three bodies. In the 3D graphical environment of the MachineLab educational software the Sun is stable, the Earth is moving on an inclined circle around the Sun and the Moon is moving around the Earth and with the Earth. The user can navigate in the space and observe the phenomena of the day and night, the way that solar radiation is applied on the Earth spherical surface during the year and hence the seasons. The phenomena of moon and sun eclipses are represented as well. The observations are implemented through the camera which can be placed, also, on the Earth or on the moon and with this functionality the issue of different frames of reference can be approached.

b. Level of abstraction

The representation is realistic in the sense that the three bodies are represented as 3D spheres having attached textures, which give to them the necessary characteristics to be discriminated. The magnitudes and distances are not proportional to the reality, since this would be impossible, but rotations are quite realistic. Space is a pictorial representation of the sky with stars. In another representation of the background there is a system of three axes in 3D space.

c. Concepts inquired

Concepts involved in the microworld are those concerning the succession of day and night, the seasons and the eclipses, all the above related to time. The inquiry is also about the concepts of circular movement, relative motion, frame of reference, position from the part of physics, building models and programming in logo language.

d. User Interface

d.1. Description of the scene

The scene is consisted of the space where the celestial bodies are sited and revolve. The user may change the view of the scene and chose between the representation of the nocturnal sky and that of the 3d Euclidean space.

d.2 Manipulation

The user can control many parameters of the simulation. He/she may change the point of view (camera) and locate it on each one of the three celestial bodies, or mount it on a spacecraft, whose movement can be controlled either with a joystick, either with the use of specific button on the keyboard. Also he/she may pause or accelerate the simulation and change the rate of time in order to modify the duration of days and years

e. Programmability

The microworld, in this version, is not supposed to promote programmability by the user. On the other hand, if the teacher decides so, the microworld can be transformed easily to a programmable environment. The user can write code in logo language constructing his/her own model or make changes in the existent model. For example the students could add another planet (spherical object), for example Mars and, using the existent routines, to put it in motion according to standards taken from the astronomy lessons.

f. Feedback from the computer

f.1 When changing the parameters

The parameters of the simulation are the location of the camera which causes alteration of the point of view, the rate of time which changes the duration of the gyrations and the background representation.

f.2 As result from the experimentation

The outcome of the experimentation is the representation of the orbits of the earth and the moon, as seen from various points of reference.

g. Mathetic procedure

The inquired concepts are to be understood through observation of the phenomenon and interpretation based on fundamental principles of physics and astronomy.

h. Didactical structure

The characteristics of the microworld permit its use in two ways:
Initially it can be used as a simulation for enquiry in order to reveal alternative ideas that the students have about the phenomena mentioned above and bring on mental conflict which, consequently, may lead the students to build right and robust interpretative models about the phenomena.
At a second level, the microworld can be used as an environment for constructionism, allowing older and more experienced in logo scripting students to construct artifacts, such as another planet, or reform the whole environment by changing the laws that dominate the phenomena.

i. Type of representations used

The scene is a 3D environment, in which the only source of light is the sun, who is day lighting the earth and the moon. Grace to the possibility for the user to navigate in the space between the three bodies, the microworld obtains characteristics of a virtual reality system. On the blue ribbon of the representation window, the user can see the exact month and day of the year, corresponding to the current position of the earth related to the sun.

j. Procedure of development

The microworld was developed by an educator with very big experience in developing microworlds with the use of Logo scripts. The final version of the simulation was reached through formative assessments, which were taken from the “Escalate” partners and the Greek “Escalate” community. The latter consists of teachers of various specialties in an in-service training on educational technology. Thus, the latest version has the possibility to be controlled with a Joy stick.

3.9 The Moving Marbles

a. Represented Phenomenon

The subject domain of this microworld is Dynamics and especially the motion of bodies on inclined and horizontal planes under the influence of gravity and of resistance forces. Moreover, the behavior of bodies during an elastic or inelastic collision could be a domain of inquiry for the user of this microworld.

A marble starts from up the slope and rolls down performing a rectilinear movement. When it reaches the horizontal surface, it changes its direction and eventually collides with the second marble, which may hit the third one. The kinetic energy is directly transmitted to the last marble being hit.

b. Level of abstraction

Although, the representation of the phenomenon looks as if it takes place in a real landscape, the representation of the marbles' behavior is very abstract. For example, the contour lines of the marbles don't bear any change regardless the fact that an inelastic or an elastic collision takes place.

c. Concepts inquired

During the inquiry process the learner could generate meanings about concepts such as: Kinetic energy, Potential energy, Gravity, Resistance forces (Static ground friction – Dynamic ground friction – Air friction), Velocity, Relative velocity, Acceleration, Position - Displacement, Elastic and inelastic collision, Coefficient of elasticity.

d. User Interface

d.1 Description of the scene

The scene where the simulation of the phenomenon occurs contains entities whose behaviors are logo programmed. The entities that may participate in the simulation are: a right slope (inclined surface), a left slope (inclined surface), a flat surface (horizontal surface) and three marbles (balls).

d.2 Manipulation

The user has at his disposal a set of sliders through which the parameters dominating the experiment can be dynamically changed. Such parameters are the mass of all three marbles, the intensity of the gravitational force, the friction coefficient, the angles of the slopes) and the initial positions of all the three marbles

Furthermore, by checking the relevant check boxes the user may remove one marble or ask the marbles to behave as if they were elastic bodies. The latter causes the Elasticity coefficient slider to appear on the microworld interface.

Finally, there are three buttons on the interface of the microworld, a "Start" button, a "Stop" button and a "Reset" button.

e. Programmability

In this microworld the "Logo" component appears on the microworld interface. Thus, the learner may choose to interfere with the logo procedures. The interplay with the logo local code may lead the leaner to decompose the procedures, gain a better understanding

of the scientific laws governing the simulation or even construct a new artifact based on his/her own ideas about the represented phenomenon.
Moreover, the microworld components such as the sliders could be otherwise connected using the event – handling feature and logo scripts. For instance, the user could connect the Marble 1 Mass and the Marble 2 Mass slider in such a way the second marble's mass value will always depend on the first marble's mass value.

f. Feedback from the computer

f.1 When changing the parameters

Despite the fact that through the manipulation of the sliders, the values of the parameters dominating the phenomenon change dynamically, not all these values get to be visually represented on the scene of the simulation. For example, the manipulation of the Initial height 3 slider causes the 3rd marble to change directly its original position on the scene interface, while the manipulation of the Marble 3 Mass slider doesn't have any direct visual effect on the scene.

f.2 As result from the experimentation

The outcome of the experimentation is the displacement of the marbles performing rectilinear movements and the collision (elastic or inelastic) to each other. A collision may take place several times during the experimentation as the direction of the velocity changes for a marble. During the simulation process, in the text boxes, located right underneath the scene, the values of the marbles' velocities and values of distance they have traversed since their original starting point are being dynamically represented.

g. Mathetic procedure

The concepts embedded in the microworld are to be understood through observation of the simulated phenomena, direct manipulation of the sliders and interpretation of the visual and symbolic representations. In this way the concepts are to be understood.

h. Didactical structure

The microworld is designed to offer the learner the opportunity to simulate experiments concerning the movement and the collision of two or more bodies. The scientific laws governing the phenomena simulations are integrated into the microworld by logo scripting. Nevertheless, the learner can customize the simulated phenomenon by deciding on the values of the sliders, on the number of the marbles being present during the simulation and on whether the collision at hand is going to be elastic or not. Furthermore, if the user wishes so he/she can interfere with logo scripts and set new rules defining the behavior of the bodies.

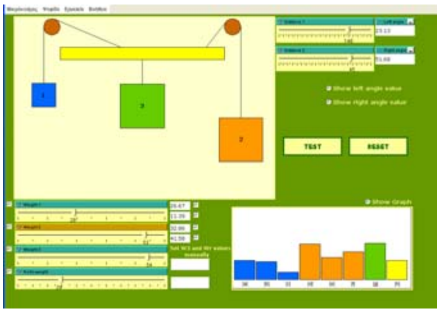
i. Type of representations used

The motion of the marbles is phenomenologically represented on the scene, while the values of the parameters involved in the simulation are mathematically (numerically) represented into corresponding text boxes. These text boxes may contain values that remain unaltered during the simulation or values (such as the velocity or the marbles) that instantly modulate to the scientific calculations.
Additionally, the learner could exploit the symbolic representation offered by the programming language and use it as a tool to underlying relationships between the concepts incorporated in the microworld.

j. Procedure of development

The microworld was the product of the collaboration between an educator and a developer. The ETL team members offered their assistance and played the role of a mediator in order to facilitate the communication between the two parts. After the initial version of the microworld, which did not include the manipulation of the resistance forces, the microworld was redesigned by the educator so as to include supplementary features. During the second stage of the development of the microworld, the educator felt more comfortable to start experiment with it. Thus, the communication with the developer became easier and for the development of the final version of the microworld no interference from the ETL team members was anymore necessary. This a typical case where as the two experts become more and more involved in the development of the microworld, they shape a common language and they start to understand each other

3.10 The Equilibrium



a. Represented Phenomenon

The subject domain for this microworld is the equilibrium and especially the equilibrium of a linear body under the influence of parallel and non parallel forces.

A rod (linear body) is being suspended from two ropes which are wrapped around a pulley and have a weight attached to their free end. The equilibrium of the linear body depends on consideration the influence of the 4 existing forces.

b. Level of abstraction

The representation of the entities is abstract, in the sense that the objects are represented as geometric figures. On the other hand since the shape of the actual objects is very close to the specific figures used for the representation, we may say that besides its abstraction, the representation has some realistic characteristics: the hanged weights are represented as square boxes, the rod as a narrow oblong (rectangular parallelogram), the pulleys as circles and the rods as straight lines.
The representation of the rod's state when it is out of equilibrium is absolutely abstract: the rod moves towards the horizontal or the vertical axis and a message appear informing the user that there is no equilibrium.

c. Concepts inquired

The concepts that are directly involved to the inquiry with the microworld are: equilibrium of a linear body, analysis and synthesis of forces, addition and subtraction of parallel forces.

d. User Interface

d.1 Description of the scene

The scene where the objects lie has no special characteristics. The sliders controlling the forces lie under the scene and the sliders controlling the angles to the right.

d.2 Manipulation

The user has at his disposal a set of sliders through which the parameters dominating the experiment can be dynamically changed. Two of the parameters, the Weight 3 and the weight of the rod, can be set manually at the relevant text boxes.
To test the equilibrium and to reset the microworld to its initial condition, two buttons are used.
The representation of the value of the resultant force and the component forces, the values of the angles formed between the suspension ropes and the rod and the whole "Graph" component may appear or disappear with the use of check boxes.

e. Programmability

In this microworld the "Logo" component is hidden so as not to allow the students to interfere with the software code.
None the less, an E-slate user (even a beginner one) could redesign the microworld by retrieving the Logo component and changing the procedures used to construct the

simulation experiment model. Moreover, the microworld components such as the sliders could be otherwise connected using the event – handling feature and logo scripts.
For instance, the user could connect the Weight 1 and Weight 2 slider in such a way that the movement of the pointer of the first one would result to a mathematically calculated displacement of pointer of the other.

f. Feedback from the computer

f.1 When changing the parameters

The dynamic manipulation of the weight values, through the use of the relevant sliders, results the dynamical change of the dimensions of the objects on the "Scene". Identically, the manual input of the Weight 3 value using the text box next to the slider, has the same result on the dimensions of the 3rd weight.
Both the dynamic manipulation of the sliders and the manual input of the values of the weight parameters have a direct influence to the bar-graph. The bar – graph represents the values of forces (resultant and components) exerted to the rod.
The dynamic manipulation of the Distance values, results the displacement of the suspension point of the rod and the change values of the angles between the ropes and the rod which are shown at a text box located next to the relevant slider.

f.2 As result from the experimentation

The result of the experimentation is of the binary form. Either the calculation of the parameters leads the rod to equilibrium and a relative message appear, or it leads to imbalance and besides the relative message that appears, the rod moves towards the vertical or the horizontal axis. The direction of the move of the rod (up-down for the vertical axis and left-right for the horizontal) depends on the resultant force exerted to the rod.

g. Mathetic procedure

The simulation provides the learner with a tool for investigating the underlying rules and scientific laws that govern the digital environment. The concepts embedded in the microworld and the relations between them become explicit through a hypothesis setting and testing procedure. Each time the learner changes the parameters of the simulated experiment, an alternative scientific situation arises and a different environment is being constructed. The exploration of this new environment leads to a reflection process concerning the influence of each parameter to achievement of horizontal or vertical equilibrium. In this sense the inquired concepts are to be understood by the user.

h. Didactical structure

The microworld is designed to offer the learner the opportunity to simulate an equilibrium experiment. At the same moment the microworld has many characteristics of a constructionist microworld. Although the learner can not intervene with the model governing the simulation nor remove or add bodies to the "Scene" component, it is more than obvious that he/she can create customized meaningful specific situations.
The dynamic manipulation of the values, through the use of sliders, leads to the construction of a different layout on the "Scene" component each time a slider pointer moves. This feature of the microworld enables the learner to simulate a different experiment each time or simulate the same experiment as many times he/she wishes.

j. Type of representations used

The Equilibrium microworld combines phenomenological representations on the Scene with mathematical representations through the bar graph and the text boxes where the parameters' values appear.

The learners can choose to base their interactions to the graphical or the symbolic (numeric) representation or use both as a tool for constructing mathematical meanings and becoming aware of underlying relationships between the concepts incorporated in the microworld.

Finally, by retrieving the logo component, the learner could exploit the symbolic representation offered by the programming language.

k. Procedure of development

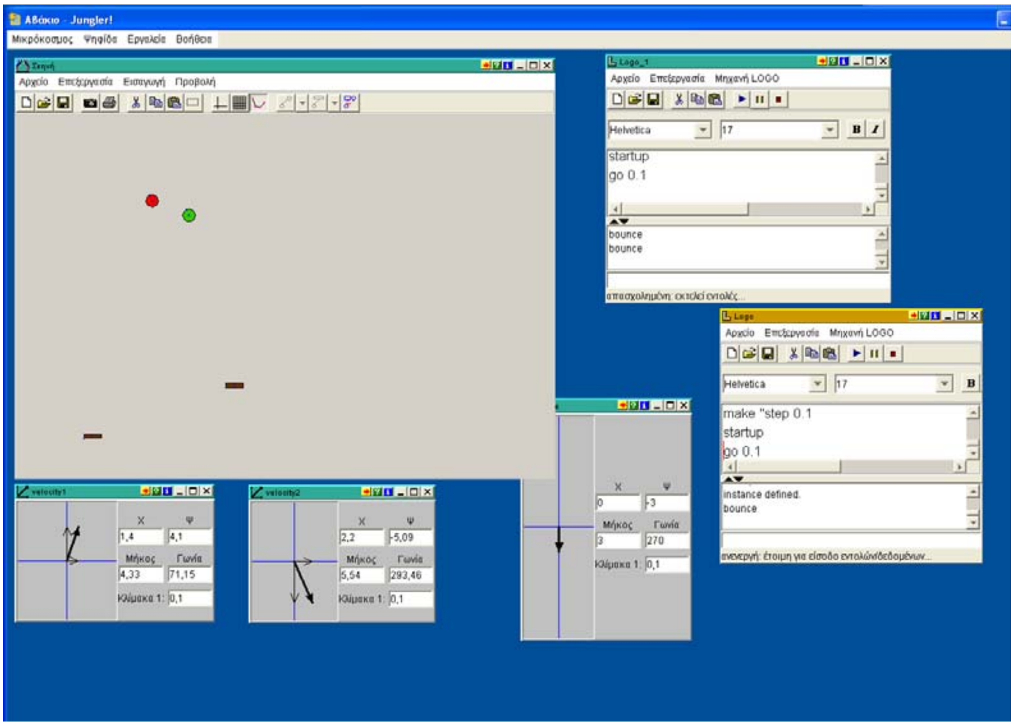
The microworld was developed after the close collaboration of two educators from whom the first has a big experience in designing microworlds for science teaching and the second is very capable in Logo programming and has just put in the design of microworlds.

The spark was a microworld designed and developed by the second teacher in the domain of tensile strength, which was supposed to be used by students in the technical and vocational education. This microworld was redesigned by the first educator in order to be used by students of the general education in the subject domain mentioned above.
The collaboration was fruitful for both educators and the development of the microworld led to a final version much richer and more interesting than the initially designed..

3.11 The Juggler

a. Represented Phenomenon

The subject domain for this microworld is velocity and acceleration in a Newtonian space. A 'Juggler' with two bats tries to keep a green and a red ball in the air. Only one bat can be moved at a time. The initial velocities and field force are set by means of dynamically manipulating respective vectors. Once the game starts, the velocity vectors become measures of velocity and thus change continually. The field force vector of course does not change once the game has started. The force can be set to the magnitude and direction of gravitational pull, but the student is free to set its direction and length to any parameters.



b. Level of abstraction

The representation of the entities is abstract, in the sense that the objects are represented as geometric figures. On the other hand since the shape of the actual objects (balls and bats) is very close to the specific figures used for the representation, we may say that besides its abstraction, the representation has some realistic characteristics. The representation of the velocities and field force however is abstract and in the form of a manipulable vector. Also, some specific conventions made with respect to the simulated physics (such as the collision rules and the angle of the bats) give a sense of abstraction to the game.

c. Concepts inquired

The concepts that are directly involved to the inquiry with the microworld are: velocity, acceleration, gravity, collision. At the same time concepts for inquiry are functional relations (time vs point on plane), change and rate of change, vectors and vectorial entities, angles (in collision rules).

d. User Interface

d.1 Description of the scene

The scene contains the two balls and bats. It is possible through the programming interface to add or take away balls and bats. There are the three manipulable vector representations. Also there are two instances of the Logo code and the game starts by executing the start commands.

d.2 Manipulation

The velocity vectors operate as controls before the game starts and as measures after it has begun. The field force vector operates in the same way, however, as a measure it remains constant. Each bat needs to be selected and then can be dragged anywhere on the field before or during the game. Only one bat at a time can be dragged.

e. Programmability

This microworld is designed for questioning the respective concepts through changes in the code of the simulation which for each ball is about one page long. The students can make changes to the velocity and field force equations, can change the rules of collision and the properties of the balls and the bats (size, mass, shape, color etc).

f. Feedback from the computer

f.1 When changing the parameters

Parameters can be changed either by changing values in the programming code or by manipulating the vectors before the game starts. Feedback is given by means of the behavior of the bats and balls during the game. The user needs to act in time to keep the balls in the air. In doing so, she/he develops strategies to anticipate the balls' trajectory based on the concepts and relations at hand.

f.2 As result from the experimentation

The results of the experimentation are open and related to the ways in which the game is setup either through the programming code or through the manipulation of the vectors and bats before the game. In a sense there is continuous results given by the game since it only stops when the user presses the stop button on the programming components. There is no 'success-failure' element to the game, when the bat misses the ball, the latter continues to travel 'out of site' and its velocity can only be seen by means of the numerical measure on the vector component. The user can stop the experiment and start again.

g. Mathetic procedure

The simulation provides the learner with a tool for investigating and questioning the scientific laws and underlying mathematical relationships in Newtonian space. When the game is setup so that these laws apply, the user can play the game and get a feel for the behavior of a particle (ball) in motion in Newtonian space. By using the vector representations they can at the same time get a feel for the essence of vectors as mathematical objects and as measures of certain entities such as velocity. However, and perhaps most importantly, the user can question Newtonian laws and make up their own by changing the rules of the game. Conversely, the game can be given to students with non-Newtonian rules and they can be given the task to convert it.

h. Didactical structure

The microworld is designed as a game to be played, questioned, changed and designed for others to play. There is a variety of didactical designs which can be applied, from task setting to more informal projects of devising games and making rules explicit. They key to the whole process is frequent reflection, argumentation and articulation of generated meanings, rules and hypotheses.

j. Type of representations used

The Juggler microworld combines phenomenological representations on the Scene with mathematical representations through the vector interface and programming code. The game can be played exclusively by means of manipulating the vectors or by an integrated approach including changes in the code of the simulation.

k. Procedure of development

The microworld was developed by researchers as a half-baked microworld, i.e. with the explicit intent to be used and changed in different ways. It has been used in a mathematics student dissertation to teach functions, in a case study to teach the meaning and functionality of vectors. It has given rise to the design and development of different microworlds such as the balloon. It was used by high-school students in a computer club to develop an ‘arcanoid’ game.

3.12 The Funambulist

This activity presents a set of tasks in the aim to facilitate the understanding of the phenomenon of "balance". The students are confronted to several exercises: observation, manipulation, construction. They are also invited to argument and discuss about their activities during the exercises.

<u>Phase 1: observing and questioning</u>

This first phase consists, as an introduction, in presenting to the students different objects/games (birds, mobiles, scales, etc.) related to the main subject: the balance. The students have to observe, examine and manipulate these objects, and also to discuss together (in small groups) about the phenomenon. At the same time, the teacher or the organizer guides the students by making some comments and remarks about the students' questions and observations.

<u>Phase 2: to construct an acrobat and to argument on it</u>

The aim of this second phase is to confront the students to a concrete example of the phenomenon of "balance": the acrobat. This one consists in a chap made of diverse, but simple, material (wooden or iron sticks, polystyrene or cotton wool balls, etc.), and which has to hold on one of his leg. To get the balance of the chap, the students have to observe, manipulate and construct their own model. And finally, they have to discuss collectively about the phenomenon (conditions, physical principles, hypothesis, etc.). To carry out this phase, the teacher has to respect the following points:

1. <u>To observe and to discuss:</u>

The students are invited to observe a collection of different acrobats (varied by their size, weight, colours, material, etc.).

Then, the teacher has to choose two acrobats (one that holds and one that doesn't) and show them to the students. These have to answer (orally or in written; individually or by small groups) to the following question: "why is one balanced and the other one not?"

Finally, the teacher asks the students about the other acrobats. They have to anticipate if one will be balanced or not and to argument on their answers.

2. <u>To construct an "acrobat":</u>

The students have now to construct an "acrobat" by their own with the material* at their disposal. The aim is to get the chap be balanced.

* Wooden or iron sticks, polystyrene or cotton wool balls, etc.

3. To evaluate the conditions of the phenomenon:

Several pictures* are showed to the students. These have to anticipate orally (individually or by small groups) about what will happen "will he be balanced or will he fall down?"

* See annex 1

4. To analyze some arguments:

A set of different written arguments are presented to the students. These have to choose, by small groups, the right ones and the wrong ones.

* See annex 2

5. Collective discussion and synthesis:

The aim is now to answer collectively to the following questions: "What allows getting the balance?" and "Which are the main conditions?"

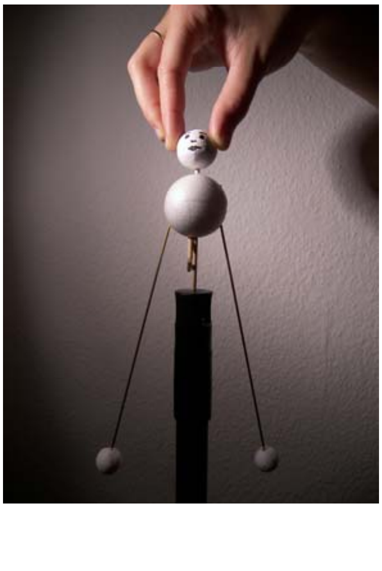
The collective discussion has to point out the following notions: gravity, forces, balance (stable/unstable).

6. Individual post-test:

The students are asked to write down individually their explanations of the phenomenon of "balance".

Annex 2: Pictures

According to the following pictures, can you anticipate if the acrobat will be balanced on his leg or if he will fall down?



Annex 3: Set of Arguments

To get the acrobat's balance, you have to…	Right	Wrong
… put sticks with the same length		
… put short sticks		
… tilt the sticks the same way		
… put weights on the extremity of the sticks		
… put light weights		
… bring the acrobat to a standstill		
… make sure that the chap isn't too heavy		
… make sure that the chap's leg isn't too short		
…		
…		

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ESCALATE: The White Book

Part III: The Design of Cases

ESCALATE: The White Book

Chapter 4: The design of cases

Y. Orad and H. Pensso

Table of Contents

4.1 Introduction

A case contains usually three elements:

- A template.
- A worksheet for students.
- A use of I.C.T. tool (Digalo, Microworld or both).

The library of cases includes 22 cases concerning various subject domains and intended to use with students of different ages; in primary schools, junior high schools and high schools. Some of the cases have been designed but haven't been implemented yet, and they are marked with an asterisk.

The cases are classified by subject domains:

4.2 Biology

List of cases:
1) Digalised-Euglenia
2) Micro organisms
3) Who is the savage who ate my cabbage?
4) Food and diet

Three of the four biology cases concern scientific issues. The first of them (Digalized Euglena) deals with the differences between cells of animals and vegetal cells. The second deals with micro organisms and the question of whether they benefit us or cause us damages. The third case (Who is the savage who ate my cabbage?) concerns a social problem – what kind of disinfestations should we choose to use for fighting damages to agriculture, that are caused by various living creatures. The fourth case concerns food and diet.

4.2.1 Digalised-Euglenia (Switzerland)

This case focuses on biological differences between vegetal and animal cells. Contrasting between those differences is thought to invite students to infer the characteristics of vegetal vs. animal cells. This differentiation is undertaken by considering the case of Euglenia, "something" that seems to stand at the border between the vegetal and the animal. The question that is handled is: Is Euglenia a vegetal cell or an animal cell and what is the difference between the two of them?

The case is intended for Grade 6 students (11-12 years old) without importance to gender. Its objective is to

- Improve pupils' scientific vocabulary
- Identify the main features of a vegetal and animal cell, and how to distinguish between vegetal and animal cells
- Familiarize with the Euglenia cell.

– Articulate scientific concepts
– Learn how to extract ad hoc information from texts

Throughout several sessions, the pupils work individually and in small groups to cope with the issue at stake. They are led to develop an enquiry approach in finding answers to some scientific questions that concern the Euglenia micro organism, looking for arguments from textual resources and defending their points of view during the argumentative phase.

During their work in class the students use a written argumentative map and a Digalo map. They also use scientific texts that concern animal cells and vegetal cells. The teacher is given a description of the scenario (a special sheet for the teacher).

Description of the interaction:

1. The students are asked about their pre notions about the cell by individually writing an essay
2. In classroom and/or at home, individually and/or in groups the students are reading texts about the animal cell and the vegetal cell.
3. Small groups sitting around a table to prepare arguments
4. In new groups, students discuss the issue through Digalo
5. in plenary teacher lead discussion with feedback and conclusive remarks
6. Students write a final essay on cells

The role of the teacher is to moderate discussions in the plenary and though digalo by giving information, synthesizing, formulating, suggesting words, asking questions and summarizing

*4.2.2 Micro organisms (Israel)**

Is bacteria harmful or beneficial for us. In everyday life, the micro organisms that are known to the students are bacteria. Students recognize bacteria as the cause of illnesses, and thus it is not surprising that many of them hold the false opinion that those bacteria (as representatives of all microorganisms) are bad and damaging. This unit's purpose is to uproot this view through an argumentative approach. Another purpose is to develop argumentative skills through the use of texts and digalo.

The case intends to do it throughout several sessions, in which the pupils work individually and in small groups. They use various texts that are intended to provide information for the discussion and digalo to present their argumentations. It is targeted to pupils of grades 9-12 (primary school). The students have to know basic concepts in biology.

The duration of the work is about 4 lessons of 45 minutes each. This can be prolonged if necessary and if possible. There is no importance to gender in carrying out the case.

To carry out their work the pupils are introduced to several texts through which they identify evidence and other kinds of support to their views, use these evidence and support and articulate arguments based on them. The students are sitting and working in groups of 5 pupils each.

The teacher is given written instructions for carrying out the work.

4.2.3 Who is the savage who ate my cabbage? (Israel)

The case concerns disinfestations through the use of idea & evidence, collaborative work, learning how to make a position by argumentation/considering evidence – supporting one of three methods of disinfestations. It relates to Ecology, men's impact on nature, food chains and agriculture. The target population to which this case is intended to is 14-16 old normative students. The estimated duration of the case is 3-4 lessons.

The objectives of the case is to discuss several kinds of disinfestations through an argumentative approach, using digalo to raise argumentations and to discuss between each other. The case also aims to develop argumentation skill for the target population (ages 14-16).

The work is carried out through collaboration between students. Here is a suggested schedule for carrying out the case:

1. 1st lesson:
   - Stage one: group work.
   - Stage two: whole class discussion.
2. 2nd lesson:
   - Stage three: group work.
   - Stage four: Presenting argumentative -maps in a whole class discussion.
3. 3rd lesson:
   - Stage 5: individual work.

During the work there is a need of access to computers during the time pupils are working with digalo. it is recommended to divide the students into pairs or groups of three or four during all the work. The groups are mixed, without any importance to gender, capabilities or other characterization. There are not any pre selected roles for students. The roles may rise naturally, during the work.

The role of the teacher during the work is to facilitate, moderate and present the issue of disinfestations to pupils. The teacher has to foster pupils to focus on evidence that support best their claim of a chosen method of disinfestation. She or he watches the pupils as they work in groups, gives advices and asks questions to support their constructing the argumentation. She or he also functions as an advisor during the discussion action (when the groups are working and when the discussion is taking place in the whole class situation. The teacher also provides stimulus textual information in the form of short pieces of scientific texts about disinfestation which gives also the basis for discussions between pupils.

4.2.4 Food and Diet (U.K)

This case was co-constructed by one teacher and a researcher. The starting point for the case design was the school curriculum for students aged 12 – 13 years, which had been adapted from the national curriculum for science. The curriculum included a focus on issues relating to nutrition, diet and healthy eating. The students were asked to work in small groups and draw on research evidence about the advantages and disadvantages of different diets. The teacher chose to focus on diets that students would be aware of, or were 'unusual', such as the Atkins diet and the cabbage soup diet. The students were to consider arguments for and against different diets and their effect on health, using Digalo.

The main objective of the case was for students to construct reasoned arguments about different diets, using evidence gained from research. They were to use Digalo software to construct arguments and to counter-argue from different positions.

The students were provided with access to a computer suite for one hour, during which time they read the research evidence and worked on constructing their arguments. The teacher began the session by introducing a context for argument using a MacDonalds hamburger and vegetable salad. She posed the question of which is the healthier option and why? She then provided a set of resource sheets to all students, posing the problem 'is this diet healthy?' and modelled arguments using Digalo icons.

Students worked in friendship groups to evaluate a particular diet, using resource sheets from the web on Atkins diet, Cabbage Soup diet. These diets were evaluated against a chart of the components of a balanced diet. Students responded to an opening question on Digalo 'is the Atkins/Cabbage Soup diet healthy?' They worked in friendship pairs to construct an argument from different viewpoints. They used information from the sheets and discussed how to place their arguments on Digalo maps.

The teacher monitored discussions and contributions by observing students and after the Digalo session asked them to review their arguments and held a plenary discussion on the pros and cons of different diets.

The students wrote up their arguments as an essay for homework.

4.3 Physics

List of cases:

1) Compressing air
2) The structure of matter
3) Marbles move
4) Sesames Ball
5) Electrical Circuits
6) Hit the Balloon
7) The Juggler
8) The Mysterious Force
9) Energy

There are nine cases concerning physics. Two of them concern dimensions in a very tiny scale (Compressing air and the structure of matter). They deal with two historical theories of the structure of matter, that were debated in the past for a very long time – the model that explains the matter as an entity consisted of moving particles with intervals between them (which is the accepted theory in our days) and the model that explains matter as a continuous entity. Two cases - "hit the balloon" and "the juggler" belongs to the field of kinematics. They refer to the study of the phenomena of motion. The case "Equilibrium" belongs to the field of statics. It refers to the study of the equilibrium of a body under the influence of forces. The case "mysterious forces" belongs to the field of dynamics and refers to the interactions between bodies under the influence of mutual forces or under the influence of field forces. Another case relates to electricity. Its essence is learning about simple electrical circuits. One other case concerns energy and deals with different sources of energy.

4.3.1 Compressing air (Israel)

The students learn and become familiar with the subject of the structure of matter, and the scientific dispute related to it. The aim of this case is to have the students reach the currently accepted theory on their own, with the help of an experiment and some demonstrations. The case is intended to students in the age 12-13 years, in mixed groups. The prior required background is knowledge and understanding about the states of matter and the differences between them. It is intended for normative population. The estimated duration of carrying out the case is about 3 lessons, 45 minutes each. There is no importance to gender capabilities or other social characterization.

The objectives of this case is to learn about the structure of matter in gas and its implications to daily phenomena, and to use the argumentative approach for learning and discussing scientific issues. The case aims also to improve and promote collaborative work between students.

In their work, pupils are using digalo for discussing and for raising argumentations, and a microworld that concerns what happens in a cylinder containing a gas. the use of the microworld is intended to the end of the case, in a stage in which summarizing the case and learning some implications of it is taking place.

In order to carry out the work there is a need for access to computers during the time pupils are working with Digalo and microworld. During the time of using the Digalo there is a need for computers for every pupil using it. The microworld activity can be done individually, or in front of the whole class. It is recommended that pupils will work in groups of 3 to 4 pupils with mixed abilities.

During the work, the pupils in a group discuss together information they have read, in order to formulate an agreed position of how to present and represent their attitude towards the structure of matter.

The role of the teacher is to watch the pupils as they work in groups, give them advices and present to them questions to support their constructing of the argumentation. The teacher should foster pupils to focus on evidence that support best their claim about the structure of matter.

4.3.2 The structure of matter (Israel)

This case intends to discuss the structure of matter through several experiments and argumentative discussions. It aims to discuss the scientific dispute related to it. The aim is to have the students reach the currently accepted theory on their own with experiments, digalo discussion and computerized demonstrations. Compared to the case "compressing air", it uses various experiments instead of a single experiment and the use of the digalo discussion is more rich and complicated.

The prior required background is knowledge and understanding about the states of matter and the differences between them. The estimated duration of carrying out the case is about 4 lessons, 45 minutes each.

The objectives of the case are to learn about the structure of matter and its implications to daily phenomena, and to use the argumentative approach for learning and discussing scientific issues. The case aims also to improve and promote collaborative work between students.

The students are working in mixed groups of 12-13 years. Each group contains 3-4 members. There is no importance to gender capabilities or other social characterization. The students have to get access to computers during the time they are working with Digalo and microworld, enough machines for group work, and blackboard or whiteboard use. The pupils in each group are discussing together information they have read, in order to formulate an agreed position of how to present and represent their attitude towards the structure of matter.

The role of the teacher is to watch the pupils as they work in groups, give advices and ask questions to support their constructing of the argumentation and foster pupils to focus on evidence that support best their claim about the structure of matter.

4.3.3 Marbles move (Switzerland)

The material settings include an apparatus consisting in a rectilinear slope and a flat surface. On the flat surface, one or several metallic marbles are side by side, immobile. A marble ball is released from the slope, and hit the marble(s) on the flat surface after a rectilinear move. When there are several marbles to be hit, the one(s) staying in the middle are (almost) not moving, because the kinetic energy is directly transmitted to the last marble. However, observing the apparatus in action, this might not be obvious, particularly when there is a small number of marbles, or when they are light in weight.

Using this setting, the students may be asked, before the marble is released, to predict what will happen. Then they are asked to describe what they have seen afterwards. The students start with one marble on the flat surface, and repeating the procedure with two marbles, three, and so on. Then, they can be provided with apparatus and may be asked to identify the relevant variables involved into the phenomenon. Older students can be asked to describe the interactions. The apparatus can also be made more complex by giving marbles of different mass, for example. In general, the students are playing with the marbles, and answering questions or problems, according to the worksheet instructions. The activity is ideally managed by making small groups of 3 students, within which an argumentative discussion can take place orally.

The case is intended for both genders from 9-10 years old to 18 or more, depending on the complexity of the task. The available worksheet proposed with this case is intende to high school students (16-18) having an appropriate mathematical background (including vectors) and some notions of kinematics. The duration is about 4-6 lessons of 45 minutes each.

The case intends to explore kinematics and dynamics, for example: to distinguish velocity and acceleration; to understand and manipulate the concept of force, as something independent of the movement; to make a symbolic description of the situation, for instance with vectors representing the forces involved in the different moments of the marbles' movement; to try to find the most relevant use of the law F=ma in this situation ; to discuss a model of the way energy is transmitted matching the marbles' movements observation in real and through the Microworld.

In addition to the material, the activities are conducted with two digital artifacts: Digalo, to create a common argumentative map from several computers, and the Microworld, which reproduces the situation as an adaptable simulator, where all parameters included into the phenomenon can be set on a quantitative scale, and some can be disabled. The Microworld should offer the possibility for the students to have an inquiry of the phenomenon through the effect of various variables, and for measuring, in order to compare it with observation of the apparatus in a real world, to construct hypothesis and verify them, and in the best case to understand the conceptualization work done in physics. Digalo can be useful to frame a written argumentative discussion among the different groups, each of them having a computer connected to a shared map for the whole classroom. This disposition requests from learners to set one position for the group through a first exchange of ideas and points of view, and to communicate and defend it towards other groups as a second step in the argumentative process.

The teacher functions as a facilitator, encouraging students to commit themselves into the activity, challenging their explanation if necessary, and guiding them towards a relevant final solution shared in the plenary discussion.

A very important social issue in this activity is for learners to acquire the ability to express ideas in science on a discursive way, justify them and explain more in depth if necessary, to reach a shared understanding within the group. Once this first level is achieved on a satisfying level, it is possible to foster learners to confront different understandings of the same phenomenon among them and argue in purpose to find the most convincing solution. The quality discussions between learners should help them to articulate the different aspects of the case, as the variables, the perception of the phenomenon and of the microworld simulation. The means used to manage these social issues are: shared discussion in small groups, Digalo mediated discussion among groups, commentaries on the Digalo maps, conclusive plenary discussion, The formative assessment is based on the recorded data on worksheets (answers and draws representing forces with vectors), and Digalo maps, and on the teacher's discussions with students. It might also take place spontaneously within peer groups, and in plenary discussion.

Summative assessment is done by the teacher, according to his usual way of testing students with an examination at the end of the physics chapter. The activity evaluation as a case uses all the material mentioned above, completed by an audio and video recording that is focused on the interaction between students using the microworld or digalo in small groups.

*4.3.4 Sesames Ball (Switzerland)**

This case discusses the action of forces on a tossed ball, including the analysis of the ball's reception. From an experiment of tossing a ball, students have to describe its movement, distinguishing the various phases of the ball, and determine the velocity changes and the forces applied on it at each phase. The students feel the ball on their hands, which might help them feel when they're applying a force on the ball. In addition, they can observe the hands going down and the up during the reception. The particularity of this case lies in this personal contact with the phenomenon: their body is included into the situation.

The students are divided into groups, where they discuss together about the various phases of the ball's movement, its characteristics, and which force is applied and when. This discussion is meant to lead to argumentative interactions, spontaneously based on differences in view among students.

The case is intended for 10th grade students and the estimated duration for it is 2-3 lessons of 45 minutes each.

The objectives of the case are focused on the strong preconceptions associated with this experiment. Many learners first think that the hand's action still applies a force on the ball while it is moving up; they rather explain the move by a distant hands' action than change their concept of force. Social interactions should be the best chances for learners to overcome this preconception. Students often think there is a force in the direction of the move, to explain it. When they draw forces, they have a tendency to give too much importance to convention and thus forgetting the schema's meaning. Others objectives might be given to this case, as to make a link between action (force) and movements (the movement of the ball in this case); describe through physics concepts a body in motion, make a progressive use of physics vocabulary and conventions, and overcome other preconceptions.

A ten pages worksheet describing several activities is available on SESAMES website, with progressive levels of difficulty, the expected preconceptions of students, and the correct answers to give as a conclusion.

Through the work the teacher asks students to give velocity variation at each phase and insists on the link between velocity variation and force, helping them to understand and prepare to Newton's laws introduction.

4.3.5 The funambulist (the acrobat)

Authors: UniNe (JFP) & ASP Ticino

i. Description of the scenario

a. Content

1. *A short description:*

Through different tasks about the "balance", the students are brought to discover the physical notions at stake. Several objects ("games") linked with the subject are presented to the students, these are encouraged to manipulate them and to think about the main subject it concerns. After this first phase, the students are asked to build an "acrobat" (funambulist; a chap holding on one leg and making the balance with his two long arms) and to argument on it. They first are confronted to different models of acrobats (variations on the size, the material, the colours and the weight) and have to argument on "Why some do hold in balance and some don't". Then they have to construct an acrobat by their own with the material at their disposal (wooden or iron sticks, polystyrene or cotton wool balls, etc.) and to get the balance (the acrobat has to hold, straight, on one leg). To get that, the students have to manipulate correctly the material (they have to choose the right size and weight) and find the right angle between the acrobat's arms. After the construction of the acrobat, the students are confronted to some pictures, which show several examples of acrobats, and they have to predict which ones would hold on one leg and which ones would not. The scenario ends with an individual post-test, which allows checking the acquired knowledge.

2. *Subject domain:*

Physics

3. *Key words:*

Forces and moments, centre of mass and gravity, stable and unstable equilibrium

4. *Argumentation:*

About prediction and explanation of the phenomenon; orally and written; individually, by small groups and collectively

b. Objectives

1. *Subject related:*

To explore Physics by discovering and applying different concepts like balance, forces, gravity. To increase students awareness of the importance of considering the diverse factors which are related to the subject: the size, the weight, the arrangement of the material. To improve the understanding of the physical principles related to the balance: stability/instability, forces and moments, mass and gravity.

2. Technology use related:

To intrigue the students, to arouse their curiosity, to stimulate the expression of hypothesis and to create a favourable climate for discussion and reflection, by using some concrete material. The students are invited to explore a physical phenomenon by observing and manipulating some simple material.

3. Social and action related:

To confront the students to a problem-situation (get the balance), to encourage them (individually and collectively) to identify de different parameters at stake, to learn to express and to check their hypothesis, to stimulate the discussion and the argumentation about the phenomenon between peers (in small groups or collectively) and to find a shared answer.

c. Time

1. Duration:

Two lessons of 45 minutes

d. Actions, materials and artefacts

1. Digital artefact:

Per group: two or three chaps made of diverse (in the size, weight, color, etc.), but simple, material (wooden or iron sticks, polystyrene or cotton wool balls, etc.), some rigged pictures and a written test.

2. Student's workbook and manual:

None

3. Teacher's instruction book and manual:

Will be described

ii. Space and students info

a. Students info:

1. Sex and age:

Male and female, 13-15 years old

2. Prior learning:

Primary and secondary education

3. Nationality and cultural background:

Swiss nationality, but diverse cultural background

4. Social status and social environment:

Will be described

5. Special needs and abilities:

None

b. Space info:

1. Organizational and cultural context:

Secondary school in La Chaux-de-Fonds (NE, Switzerland)

2. Physical characteristics:

Classroom, laboratory of chemistry

iii. Social orchestration

a. Grouping

3.1.1. Setting:

Activities with real artefacts in small groups (2-3 persons)

3.1.2. Grouping criteria:

Grouping according to friendship criteria

b. Interaction

3.2.1. Characteristics of work:

Playing with objects related to the balance, inquiring and discussing individually/in small groups/collectively about the phenomenon and the different variables, constructing an equilibrist with simple material, analysing pictures and answering to a written test

3.2.2. Support by the tutor(s):

To guide the students in their inquiry, to encourage them to formulate questions and hypothesis and to support argumentative activity.

3.2.3. Teacher's approaches:

Facilitator, guiding the students through the task by explaining the rules and answering the students' questions.

iv. Assessment procedures

a. Formative assessment

1. Interviews with students:

Will be described

2. Observations notes:

Will be described

3. <u>Peer assessment:</u>

Within the small groups, during collective discussion, by Digalo

b. Summative assessment

1. <u>Essays:</u>

Will be described

2. <u>Tests:</u>

Will be described

3. <u>Performance:</u>

Will be described

4. <u>Mark sheet:</u>

Will be described

v. Evaluation

a. Interviews with students

Probably

b. Taping and videotaping

Videotaping: focus on the interaction between students (small groups, by constructing the equilibrist and during the collective discussion).

c. Questionnaires

Written test at the end of the experimentation

4.3.6 The Light

Annexes

a. Annex 1

Didactic activity: The light

General objectives

The activity is structures 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 argomentative discussion and the study of materials.

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

From a complex question (*What is the light?*), students elaborate hypothesises and arguments. They use the documents provided by the teachers. Debating with other students defending a different standpoint, they build knowledge about the topic of light 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 from 1) to 7)
Second session (one week later): steps from 8) to 12)

First session:
1) Teacher's welcomes students and presents the researchers.
2) Pre-test: Individually, students fill a short questionnaire on pre-conceptions (see annex 2, answers will be used to form groups)
3) Teachers shortly presents the activity (general information about the goals, the steps and the organisation of groupworking)
4) The teachers introduces the phenomenon of light (front lesson)
5) The teachers illustrates the documents provided to the students
6) Students individually study the documents, they can take notes (individual task)
7) Group formation, the teacher and researchers elaborates questionnaires during the individual task and group students in such a way that students with different pre-conception discuss in the same group

Second session:
8) Preliminary groupworking: the classroom is split in 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)
9) Presentation of Digalo
10) Plenary discussion (with Digalo/without Digalo)
11) Post-test: individually, students answer a short questionnaire
12) Debriefing: final classroom discussion about the experience

Annex 2

Scenario 3: the light
(Guidelines for the teacher)

General presentation
As a complex phenomenon, the o light represents a very interesting learning object.
Find more information on Wikipedia: http://it.wikipedia.org/wiki/Luce and related link.

Pedagogical objectives
Developing new knowledge about the light, the corpuscular or undulatory nature of light, the colours, etc.
Developing the capacity to argument in a scientific subject, supporting standpoints with the knowledge and the data acquired during the study

Scenario structure

1) A short welcome (don't say to much at the beginning because we would like to know the students "pre-conceptions" with respect to the topic)

2) Pre-test: Individually, students fill 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?

   a. *The light is made of waves or particles?*
   b. *How fast is the light?*
   c. *Which colour is the light?*
   d. *Where and why the rainbow forms?*
   e. *Why do we darken by the sunlight?*
   f. *Why people in the desert wear white dresses?*

Thanks!

Do not forget to gather questionnaires and keep them accurately!

3) Few word to thank students and present the following of the activity (general information about the goals, the steps and the organisation of groupworking)

4) General presentation for the classroom starting from some documents or a power point

5) Forming the groups in function of the pre-test answers (in such a way to have relatively homogeneous groups with respect to the standpoints; during the discussion, groups defending different hypothesises can be joined)

6) Groupworking: elaboration of arguments and writing of the “argomentative chart” with respect to the following questions (to be adapted to students knowledge level):
   - The light has a particle or wave nature?
   - From what derives the speed of light?
   - From what derive the colours of objects?
   - Why, exposition to light being equal, some objects warm up more or less?
   - How does melanin work in our cellules?

7) Presentation of Digalo

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

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

   Please, answer the following questions.
   Name:

   For you, what is the light?
   a. *The light is made of waves or particles?*
   b. *How fast is the light?*
   c. *Which colour is the light?*
   d. *Where and why the rainbow forms?*
   e. *Why do we darken by the sunlight?*
   f. *Why people in the desert wear white dresses?*

Thanks!

10) Final debriefing about the experience

4.3.7 Electrical Circuits (U.K.)

The case concerns learning some simple features of electrical circuits. It concerns some prominent features related to electrical circuits like resistance, wires and battery.

In their work students discuss how electrical circuit work in different configurations and in different practical circumstances. The teacher uses a concept cartoon to explore children's ideas and then uses Digalo to argue conflicting positions on the possible wiring of a circuit to obtain the result required. It is intended to primary school students in the age of 10-11 years. Its estimated duration is 4-6 hours.

The objectives of the case are:

- To learn about the role of conceptualization and planning an experiment before doing a practical activity.
- To use correct language for the activity.
- To consider what proof will be needed to show whether the students have developed the correct conceptualization.
- Use of the Digalo software to argue about and reflect upon the conceptualization of an experiment and planning a practical activity to prove that the arguments are correct.
- Discuss and synthesize ideas to write arguments.

If the group is gifted and talented then they need only the background knowledge of previous curriculum introduction to electricity earlier in their school career. Other groups will need lessons on electricity before this activity.

For work, the students have to get access to computers. Each group works on a computer and uses a whiteboard for concept cartoons.

During the work the teacher provides concept cartoons. Students begin to discuss the nature of the practical problem and come to a joint decision about how a circuit would be wired. Misconceptions may be about flow of electricity, resistance in wires and the effect of components in a circuit on the flow of electricity.

The teacher begins the lesson with a discussion though the concept cartoon and gives the pupils an opportunity to ask questions for about 10 minutes. The visual material should engage pupils and motivate them to think about the concepts underlying the practical aspects of the use of electrical circuits. The pupils are moving on to argue about their understanding of the practicalities that will produce the result they require of the circuit. The teacher supports group activity by talking through their ideas, asking them to justify their reasoning and debate their ideas with one another until they are both convinced that they have reached the correct decision on the circuitry needed. The teacher then asks all groups to consider what equipment they will need to prove that they have reached the right decision.

The teacher will provide wires, batteries, switches and bulbs to allow practical demonstration of the circuit. There will also be equipment available that they can use to prove the circuit is correct e.g. light meters and a black box to test the brightness of the bulb(s) wherever placed in the circuit.

The teacher provides concept cartoons that enable students to engage in argumentation, introduces cognitive conflict, questioning, problem solving, decision making and addressed misconceptions. The teacher also provides equipment and assists with their experimentation.

during the research stage it is important to capture oral interaction. The record of the arguments and changes in arguments is captured on Digalo. It is important to capture verbal interaction to discover focus, involvement, arguments which were lost (not recorded on digalo), ability and gender discrimination.

4.3.8 Hit the Balloon (Greece)

The case concerns the motion of two bodies. It treats it through a balloon taking off from the ground. The balloon is taking off the ground, moving with a constant vertical velocity. After some time a stone is thrown upwards with a vertical initial velocity aiming at the balloon. Initially, the students study the two motions separately and then study the phenomenon of the two bodies meeting.

The case is intended for using in the ages of 13 to 14 years without importance to gender. Its estimated duration is 6 lessons of 45 minutes each.

The objectives of the case are:

- To study the basic types of motion.
- To study the complex phenomenon of two bodies meeting, through experimentation and trial and error procedures.
- To scrutinize the main concepts of kinematics, namely, shift, distance, velocity, relative velocity, speed, acceleration.
- To understand the multiple representations created by an exploratory digital environment (microworld's software)
- . To manipulate a real life situation, by using a PC simulation.
- To use an interactive digital environment for argumentation and creative exchange of opinions and ideas (digalo)
- To experience team work.
- To experience a discussion based on argumentation.

To carry out the case there is a need for a computer for every student' group, a whiteboard, a computer for the teacher and a video projector so that the class can have access to what the teacher wants to show.

The prior learning needed is familiarization with graphical representations, knowledge about the difference between vectorial and scalar magnitudes and the basic terminology of kinematics.

Description of the interaction:

1. Familiarization with the digital environments.
2. Study of the Balloon's motion. Rectilinear motion. Graphical representation of the oscillation of velocity, shift and distance from the point of reference.

3. Study of the box's motion, decelerated motion, graphical representation of the oscillation of velocity, shift and distance from the point of view of the reference.
4. Discussion through the digalo environment about what the representations stand for.
5. Meeting of the box and the balloon: Graphical representation of the oscillation of velocity, shift, distance from the point of view of reference and relative velocity. Discussing the conditions for not meeting between the two bodies through digalo environment.
   The teacher tours the groups to maintain focus, facilitate and animate the enquiry in the microworld environment and support the argumentation.

   Also, he/she enhances enquiry and investigation and promotes rational reasoning during the argumentation procedure. Instead of giving the correct answers, he or she provides evidence and stimulus materials in order to provoke cognitive conflict and help the students reorganize their ideas about kinematics.

   The formative assessment are done by semi-structured interviews with each group's members to elucidate their ideas

   Also the teacher takes notes about the experimentation of each group and uses digalo charts for the assessment of the argumentation procedure.

   In a class plenary, every students group presents its conclusions and comments and judges other groups' conclusions.

   Summative assessment is done by using the answers written on the worksheets and by explanations of the students using the microworld environment.

*4.3.9 The Juggler (Greece)**

The juggler case concerns concepts of kinematics through using a simple computerized game. The user uses balls and rackets, built on the E-slate sofftware. The educational intention of the game is to build a simplified model that embodies specific notions of mathematics and science and to apply mathematical concepts in a virtual realistic phenomenon. The students are invited to control the virtual environment and change variables, making meaningful conjectures while playing the game. They have to try to juggle two balls using two rackets, in order to keep the balls from falling down. The balls move according to functions whose variables can be dynamically changed by students through the manipulation of vector representations.

The case is intended for the ages of 9 to 12 years without any importance to gender, ability or interest in science. It lasts for an estimated 1-3 lessons (45 minutes each), depending on the available time and teacher's specific educational agenda.
In their work the students use a microworld that works on the e-Slate software. The students use rackets and change the bodies' velocities by manipulating the available vectors. They also use digalo to argue and to discuss their notions within the frame of the working team.

The objectives of the case are:

- To construct ideas about motion in the field of gravity.
- To understand how velocity and acceleration are combined during the motion.
- To visualize the curve of parabola and understand its characteristics.
- To use the game to motivate and engage pupils and enhance them to formulate their ideas about mathematical and scientific concepts.
- To manipulate a real life situation, by using a PC simulation.
- To use an interactive digital environment for argumentation and for discussion (Digalo).
- To collaborate in small groups.

The equipment needed is a computer for every student' group, a whiteboard, a computer for the teacher and a video projector so that the whole class will have access to what the teacher wants to show. the necessary software is E-Slate and Digalo

No prior learning is needed to carry out this case.

The activity is assessed by semi-structured interviews with each group's members to elucidate their ideas. The teacher takes notes about the experimentation of each group and uses the Digalo map for the assessment of the argumentation procedure. There is a use of peer assessment: In a class plenary, every group presents its conclusion and comments and judges other groups' conclusions.

The evaluation is carried out by interviews with students and tutors, questionnaires, audio and video taping.

The role of the teacher is to tour the groups to maintain focus, facilitate the enquiry in the microworld environment and support the argumentation. The teacher have to act as a facilitator (he or she helps students to handle the microworld's environment, guides them to experiment and helps them to organize the discussion in the Digalo environment) and to encourage students to overcome difficulties they face).

*4.3.10 The Problem of equilibrium (Greece)**

This case introduces the equilibrium issue and is intended to promote the understanding of the equilibrium of a linear body under the influence of 4 forces. The students work with a digital microworld. At the first level they study the equilibrium under the influence of parallel forces. At a second level the students study the equilibrium of a solid body when the forces are not parallel. Also they study the analysis and synthesis of forces. During their study, the students change all the parameters that dominate the equilibrium such as the magnitude of the forces, the weight of the body and the angles between the body and the exerted forces.

The case is intended to ages 14 to 16 years without importance to gender. The estimated duration of carrying out the case is 5 class periods (45 minutes each).

The objectives of the case are:

- To make a coherent description of the phenomenon of equilibrium.
- To understand the distinction between observation and theoretical analysis.

- To make hypothesis in order to explain a phenomenon.
- To analyze forces on two vertical axes.
- To compose a resultant force from its two components.
- To add and subtract forces using the analysis to components.
- To manipulate a real life situation, by using a PC simulation.
- To use an interactive digital environment for argumentation and for creative exchange of opinions and ideas (Digalo).
- To collaborate in small groups.
- To participate in a discussion based on argumentation.

During their work the students use a microworld based on the e-Slate software. They use the digalo software to discuss and to pose argumentations.

For their work the students have to be familiarized with the digital environment and to the ways they can control it. Also they must have been taught about forces and Newton' laws (especially first and third law), about vectors and the operations between them, elementary trigonometry and analysis and composition of forces.

The indispensable equipment is a computer for every student' group, a whiteboard, a computer for the teacher and a video projector so that all the class will have access to what the teacher wants to show. Computers must be connected to a local network.

The necessary software is E-Slate and Digalo.The discussion in Digalo will take place through Internet and will be organized in a way that will permit every student of the group to work from his/her personal computer at home.

The suggested sequence of the interaction is:

1. Familiarization with the digital environments.
2. Studying the behavior of the body when only parallel forces are exerted on it.
3. Analyzing a force to two components and composing the resultant force from the two components.
4. Correlating the lengths of the ropes from which the rod is suspended with the angle between the forces and the linear solid body, analyzing the forces exerted to the rod by the ropes to two vertical components and studying the equilibrium on axis X and on axis Y.

The Formative assessment is done by interviews with students, semi-structured interviews with each group's members to elucidate their ideas. It also is carried out by observation notes like taking noted by the teacher about the experimentation of each group. The formative assessment also uses peer assessment: in a class plenary, each group presents its conclusion and comments and judges other groups' conclusions.

The Summative assessment is done by assessing answers written by students on the worksheets.

The evaluation is done by interviews with students and tutors, by questionnaires and by audio and video taping.

The teacher tours the groups to maintain focus, facilitate the enquiry in the microworld environment and support the argumentation process. She/He acts as a facilitator (helps students to handle the microworld's environment, guides them through the experimentation and helps them to organize the digalo discussion. She/He encourages students to overcome difficulties they face and to tackle the questions). Also, She/He enhances enquiry and investigation and promotes rational reasoning during the argumentation procedure. Instead of giving the correct answers, She/He provides evidence and stimulus materials to provoke cognitive conflict and to help the students reorganize their ideas about forces and static equilibrium.

*4.3.11 The Mysterious Force (Greece)**

This case discusses the issue of forces that acts without contact. The students using a digital microworld, that shows two moving spherical bodies. At the first level they study the motion trying to imagine the nature of the forces that are exerted between the bodies and conclude about the physical parameters of the phenomenon (nature of the bodies, relation of their masses etc). At a second level the students can define the values of certain parameters, such as bodies' distance, bodies' masses and the measure and the direction of the exerted forces and they have to set up the environment so that the bodies behave in a specific manner.

The case is intended to normative students of ages 13 - 14 years without importance to gender. The estimated needed duration to carry out the case is 5 class periods (45 minutes each).

The objectives of the case are:

- To make a coherent description of the phenomenon.
- To understand the distinction between observation and theoretical analysis, to make hypothesis in order to explain a phenomenon
- To relate acceleration, mass and force, to studying the conservation of momentum.
- To understand the characteristics of internal forces in a system of bodies.
- To manipulate a real life situation, by using a PC simulation.
- To use an interactive digital environment for argumentation and creative exchange of opinions and ideas (DIGALO).
- To collaborate in small groups.
- To experience a discussion based on argumentation.

In order to carry out their work, the students have to be familiarized with the digital environment. Also they must have been taught about forces and Newton' laws, gravity, electric forces and magnetic forces.
The necessary software is MACHINE LAB and DIGALO. The discussion in DIGALO takes place through Internet and is organized in a way that permits every student in the group to work from his/her personal computer at home, because the software does not allow alternative users to participate in the discussion from the same computer.
The students use a microworld based on the MACHINELAB software showing two moving bodies. They can open the Logo script and change the values for the masses, forces and the bodies' initial distance. They use also the digalo to conduct and visualize their discussion.

The suggested sequence of the interaction is:

1. **Familiarization with the digital environments.**
2. **Study the two bodies' motion as an internal force is exerted between them.**
3. **Study of complex problems with the moving bodies.**

The formative assessement is done by semi-structured interviews with each group's members to elucidate their ideas. The teacher also takes notes concerning the experimentation and argumentation of each group and uses the digalo. In a class plenary, every students' group presents its conclusion and comments and judges other groups' conclusions. Summative assessment uses students' answers written on the worksheets. There are no tests for summative assessment.

The evaluation is done by interviews with students and tutors, questionnaires, taping and videotaping.

The teacher tours the groups to maintain focus, facilitates the enquiry in the microworld environment and supports the argumentation. She/He acts as facilitator - helps students to handle the microworld's environment, guides them through the experiments and helps them to organise the discussion through Digalo. She/He encourages students to overcome the difficulties they face and encourages them to tackle questions. Also, She/He enhances enquiry and investigation and promotes rational reasoning during the argumentation procedure. Instead of giving the correct answers, She/He provides evidence and stimulus materials in order to provoke cognitive conflict and help the students reorganize their ideas about dynamics, field forces and the Newton's laws.

4.3.12 Energy (UK)

This case was co-constructed by one teacher and a researcher. The starting point for the case design was the school curriculum for students aged 12 – 13 years, which had been adapted from the national curriculum for science. The curriculum included a focus on issues relating to renewable energy sources, in particular the environmental aspects of generating electricity from such sources. The students were asked to work in small groups and carry out their own research into one of four renewable energy sources: hydroelectric, tidal, wind and 'poo' power (from animal waste). They presented the findings of this research to the whole class, and then designed fact cards, highlighting the pros and cons of their allocated energy source. Students used these fact cards to argue for the 'best' source of energy, using Digalo software.

The main objective of the case was for students to construct reasoned arguments about different energy sources, using evidence from the fact cards. They were to use Digalo software to construct arguments and to counter-argue from different positions.

The teacher introduced argumentation through the context of mobile phones, and through using an argument 'should cannabis be legalised?' as a way of modelling argument on the Interactive Whiteboard. She then provided resources for students to carry out their own research on one of the four energy sources. Students researched in friendship groups the advantages of one of hydroelectric, tidal, wind and poo power. They presented the outcomes and made fact cards of advantages and disadvantages of their chosen energy source. After the presentations from each group of students, and the construction of the cards, the students were provided with access to a computer suite for one hour, during which time they were asked to read the fact cards and work on constructing their arguments.

The teacher began this Digalo session by modelling arguments using Digalo icons. She then provided the set of fact cards to all students, posing the problem. These were used by the students to argue in pairs for the best source of power. Students used information on cards and discussed how to place this on Digalo maps. The teacher monitored discussions and contributions by observing students and after the Digalo session asked them to prioritise their arguments and present their best argument for homework.

4.4 Astronomy

List of cases:

1) Sedna, Planet or not
2) Night and day
3) The Seasons
4) Phases of the Moon (France)
5) Astronomy - the "History" case
6) A Thinking journey to the Day and night cycle: To the moon and back
7) A thinking journey to the Day and night cycle: A computerized model of the moon phases
8) Storms

There are 8 cases in this section. Most of them concern the solar system. 5 are astronomical cases that deal with phenomena that affect our daily life: night and day, the seasons and the phases of the moon. These cases involve students and give them tools for trying to present some scientific explanations about how these phenomena can be explained by the relative movements of one or more of the following celestial bodies: earth, moon and sun.

Another case that concerns the solar system, Astronomy - the "History" case, encounters the students with a historical debate that concerns two different models for the solar system – the heliocentric model (which is the accepted model nowadays) and the geocentric model.

Yet another case in this regard encounters the students with the definition of a planet. It does it by discussing a recently discovered object at the rim of the solar system called Sedna. The students have to argue if it is a planet or not, and to base their claims on evidence given to them about this body (Sedna).

One case concerns an issue that belongs to what happens on earth. It deals with the behaviour of a storm. The students are invited to develop an enquiry approach in finding answers to some scientific questions that concern storm, looking for arguments from textual resources and defending their points of view during the argumentative phase.

4.4.1 Sedna, Planet or not (U.K)

This case discusses the status of sedna in particular – is it a planet or not, and the definition of a planet in general. There are millions of objects in the universe, ranging from huge stars to dust particles. Somewhere between the two extremes are planets, but when is a planet a planet and when is it just a big lump of rock? Sedna is a recently discovered object at the rim of the solar system and up to now there was a debate over whether Sedna is a planet or just another space body (in 2007,a new definition of a planet has been accepted in Prague. In light of this decision, Sedna cannot be called a planet). In this case pupils grapple with the question of weather a celestial body is a planet or not and use evidence to decide on Sedna's status.
The case is intended to students of 12-13 years with mixed abilities.
The estimated duration needed to carry out the case is approximately 90 minutes.

The objectives of the case are:

- To learn about the role of evidence in science by evaluating the evidence provided on the recently discovered Sedna.
- Deciding whether the evidence supports the idea that Sedna is a planet, an asteroid or whether it is neither planet nor asteroid.
- To create and visualise and argument by using digalo.
- To carry out discussions, synthesize information and write arguments.

To carry out the case the students need background information on the Kuiper Belt and Oort Cloud, as well as reference material about other planets in the solar system in order to compare their ideas of Sedna to what is known about other planets.

The students need access to computers – each pupil having a computer, enough machines for group work, and Whiteboard use. There is a need for equipment to present pictures and a slide show about Sedna. Students will have evidence cards.

During the work students use evidence base to discuss the nature of the evidence and make decisions.

The assessment uses Digalo to elicit the arguments that are as relevant as possible to the specific argumentation. There is a use in the Toulmin model – depth and breadth of argument.

The teacher begins the lesson with a presentation on Sedna, giving pupils the opportunity to ask questions. The presentation lasts approximately 10 minutes and should include a lot of visual materials in order to motivate and engage pupils in the subject. Before moving on to the next activity, the teacher has to stress that the importance of the lesson is how the answer is decided from the evidence and how the decision is justified. The teacher supports group activity by talking through their ideas, asking them to justify their reasoning and debate their ideas with one another. Groups who finish quickly can be asked whether they have enough evidence to support their ideas, and can be given the second set of evidence cards to consider. The plenary with the whole class involves groups, report their discussions and final decision, using the Digalo replay.

The teacher provides stimulus materials and sources of evidence that enable students to engage in argumentation, introduces cognitive conflict, questioning, problem solving, decision making.

The teacher explains to the students that they are doing the kind of work scientists do, namely evaluating evidence, debating about ideas and justifying claims. the students reflect on their ideas as they are shown in the Digalo replay and elaborate upon them or clarify their ideas to others.

Evaluation of the case is made by Interviews with students and tutors, taping and videotaping and the record of the end argument that is captured on Digalo. It is important to capture verbal interaction to discover focus, involvement, arguments which are not recorded on digalo, ability and gender discrimination. It also made by questionnaires.

4.4.2 Night and day (France)

This case concerns the issue of day and nigh from a point of view of referential (frames of reference). The pupils construct and co-construct the problem of referential (frames of reference) in order to understand why there are night and day.
It is intended to mixed groups of 8-9 and 10-11 years old and the estimated duration of each session is approximately 45 minutes to 1 hour. The entire case lasts approximately 5 hours.

The objectives of the case are to:

- Explore the students' first representations and try to drive them toward a scientific explanation of the phenomenon of day and night.
- To learn to use the science discourse (have hypothesis, try to prove it with specific tools, find evidence…).
- To use Digalo and microworld as well.
- To Experience in writing of arguments.
- To construct knowledge from texts.

In order to work, the pupils may have a workbook to be used in order to follow some instructions about the Earth-Moon and Sun system, where they will note their observations of natural phenomenon, and some historical resources adapted to young students and other scientific texts. Drawings may be used as well. They have to know a few elements of astronomy (depending on the school level). There is a need for one computer for 3 or 2 students.

A suggested sequence of the interaction:

1. Beginning with a controversial question proposed by the teacher (Why are there nights and days?).
2. The pupils have to answer this general question in a workbook where several questions around this topic are proposed in different forms.
3. An inquiry approach is then proposed through observation (of the sun, or the moon) and manipulation (they may use some materials in order to simulate the movements of the Earth and the sun and the Moon) in order to propose some hypothesis and to begin to test them. This inquiry approach could be a real one through manipulation of objects or a virtual one through a microworld.

4. A debate (oral one or through digalo) will be proposed by the teacher in order to confront the hypothesis and the results of the different collective explanation and to select which hypothesis fulfils all the different conditions.
5. To conclude, the first exercises proposed at the beginning of the activity are also proposed at the end of it.

The assessment uses observation notes and peer assessment (a representative of each group presents the collective work).

The evaluation uses taping, videotaping and questionnaires.

4.4.3 The Seasons (France)

This case deals with the issue of seasons from a point of view of referential (frames of reference). The pupils construct and co-construct the problem of referential (frames of reference) in order to understand how seasons are created. They learn about relative movements of translation and rotation in order to understand this issue (the seasons).

The case is intended to mixed groups of 8-9 years old and 10-11 years old. The estimated duration of carrying out the case is approximately 5 hours (around 45 minutes-1 hour per proposed activity such as argumentative session on Digalo or modelling activity, etc).

The objectives of the case are:

- To try to drive the students toward a scientific explanation of the phenomenon of seasons after exploring their first representations.
- To learn to use the science discourse (have hypothesis, try to prove it with specific tools, find evidence…).
- To use Digalo and microworld.
- To Experience in writing arguments within a group.
- To construct knowledge from texts within a group.

For their work, the pupils need a workbook to be used in order to follow some instructions about the Earth-Moon and Sun system, where they will note their observations of natural phenomenon, some historical resources adapted to young students and other scientific texts. Drawings may be used as well. They have to know a few elements of astronomy (depending on the school level). There is a need for one computer for 3 or 2 students.

A suggested sequence of the interaction:

1. Beginning with a controversial question proposed by the teacher (Why are there seasons?)
2. The pupils answer this general question in a worksheet where several questions around this topic are proposed in different forms.
3. An inquiry approach is then proposed through observation (of the Earth and of the Sun) and manipulation (they may use some materials in order to simulate the movements of the Earth and the Sun) in order to propose some hypothesis and to begin to test them. This inquiry approach can be assisted by manipulation of real objects or a virtual object (a microworld).

4. A debate (oral one or through digalo) is proposed by the teacher in order to confront the hypothesis and results of the experimentation and to select which hypothesis fulfils all the different conditions.
5. To conclude, the first exercises proposed at the beginning of the activity are also proposed at the end of it.

The assessment uses observation notes and peer assessment (a representative of each group presents the collective work).

The evaluation uses taping, videotaping and questionnaires.

4.4.4 Phases of the Moon (France)

This case deals with the issue of the phases of the moon. The pupils have to discuss and to explain why there are different shapes of the moon. The pupils construct and co-construct the problem of referential (frames of reference) in order to understand how these phases are created.

The case is intended to mixed groups of 8-9 years old. The estimated duration of carrying out the case is approximately 5 hours cut into several 45 minutes to 1 hour sessions.

The objectives of the case are:

- To try to drive the students toward a scientific explanation of the phenomenon of the the moon phases after exploring their first representations.
- To learn to use the science discourse (have hypothesis, try to prove it with specific tools, find evidence, etc).
- To use Digalo and microworld.
- To Experience in writing arguments within a group.
- To construct knowledge from texts within a group.

For their work, the pupils need workbook to be used in order to follow some instructions about the Earth-Moon and Sun system, where they will note their observations of natural phenomenon, and some historical resources adapted to young students and other scientific texts. Drawings may be used as well. They have to know a few elements of astronomy (depending on the school level). There is a need for one computer for 3 or 2 students. Also, the students have to get access to the digalo and to the microworld concerning the case.

A suggested sequence of the interaction:

1. Beginning with a question proposed by the teacher - Why is the shape of the moon changing?
2. The pupils answer the question in a worksheet. Then they answer a questionnaire where several questions around this topic are proposed in different forms.
3. An inquiry approach is then proposed through observation of the moon. The students have to note their longitudinal observation during some period and draw the shape of the Moon. From their observations and narrations about them, several questions would be asked. The teacher directs the pupils' attention to the question of "when does the shape of the moon change?"

inciting them to compare in group their observation and the date when they had made it. The pupils are invited to construct a moon calendar. Then the teacher proposes to enter in the explanation of such a phenomenon. The teacher has to work in small group in order to find a hypothesis.

4. A debate through digalo is proposed by the teacher in order to confront the hypothesis and results of the different collective explanations and to select which hypothesis fulfils all the different conditions.
5. To conclude, the first exercises proposed at the beginning of the activity are also proposed at the end of it.

The assessment uses observation notes and peer assessment (a representative of each group presents the collective work of the group).

The evaluation uses taping, videotaping and questionnaires.

4.4.5 Astronomy - the "History" case (France)

In this case pupils construct and co-construct the problem of referential (frames of reference) in order to understand the relative motion of earth the earth and sun. The pupils are learning about relative movements of translation and rotation. The question to discuss is what is the convenient model for the solar system and how the problem of finding this model was initiated and debated thought History.

The case is intended for mixed groups of 10-11 years old students. It is intended for 1 session of about 45 minutes each per week for a total of 6-7 sessions which may include a visit to the Cité de L'espace (3-4 hours visit tour)).

The objectives of the case are:

- To explore the students' first representations.
- To try to drive the students towards a scientific explanation the phenomenon of the seen movement of the sun in the sky.
- To learn to make science (have hypothesis, try to prove it with specific tools, find evidence…)
- To learn how to use Digalo and then microworld as well.
- To learn how to choose information in order to write together arguments
- To learn how to read documents in order to construct knowledge on the subject.
- To experience a phenomenon (in a virtual or real way).
- To model a phenomenon and construct results.

For their work, the pupils need a workbook to be used in order to follow some instructions about the Earth-Moon and Sun system, where they will note their observations of natural phenomenon, and some historical resources adapted to young students and other scientific texts. Drawings may be used as well. They have to know a few elements of astronomy (depending on the school level). There is a need for one computer for 1 or 2 students. Also, the students have to get access to the digalo and to the microworld concerning the case.

A suggested sequence of the interaction:

1. Beginning with a controversial question proposed by the teacher through historical documents: the model of Copernicus and the model of Ptolemy for the solar system (What is the place of the Earth and the Sun in the system, what are the kinds of movements of those bodies? Who is right? Why?)
2. The students search documents in order to understand Copernicus model versus Ptolemy model and to answer some questions and complete the documents given by the teacher. They construct arguments, first individually and then within small groups in favour of these two models.
3. An inquiry approach is proposed through search on Internet or books about the solar system, observation (of the Earth and of the Sun) and manipulation (the students may use some materials in order to simulate the movements of the Earth and the Sun) in order to propose some hypothesis and to begin to test the two models. This inquiry approach could be a real one through manipulation of objects or a virtual one through a microworld use.
4. A debate (oral one or through Digalo) is proposed by the teacher in order to confront the hypothesis and results of the modelling and to select which hypothesis fulfils all the different conditions.
5. In the end, a written conclusion is proposed by the students, assisted by the teacher that discusses the different hypothesis and presents the accepted model of the solar system.

The assessment uses observation notes and peer assessment (a representative of each group presents the collective work of the group).

The evaluation uses taping, videotaping and questionnaires.

The teacher has to focus the pupils ‘attention and facilitate their activity of inquiry.

4.4.6 A Thinking journey to the Day and night cycle: To the moon and back (Israel)

In this case students use pictures of the earth and the moon, in order to create an imaginary journey, in which students learn the concepts of day and night in the context of the earth and the moon while constantly changing their perspectives. The case is based on "Thinking Journey to the Moon" (Schur, 1998). The case enables students to put themselves inside the picture, experience the day on the moon and understand the concept of day while comparing its appearance on the moon with its different appearance on earth. Students experience the nature of day on the moon with the use of the two pictures that are brought at the end of this short description and also by asking the students to draw a drawing of the Earth from the perspective of the Moon. The goal is to transform students' concept of day and night from an egocentric view based on their experiences on the Earth to a broader one that can be implemented to other celestial objects.

The case duration is 3 encounters of 2 hours each. It is intended for 8th grade pupils but was tried also in 2nd degree students (ages 25+) and is relevant to both.

In their work the students use Digalo, workbook and manual. The manual includes a framework story on a detective that wishes to resolve the mystery of day and night. Students receive the story, the instructions and the pictures inside closed envelopes. The teacher uses a teacher's guide book that contains the same activity given to the students, and also the time frames, instructions for mediating and instructions on how to summarize the discussion.

Students are first asked to draw a picture of the earth as it appears from the moon, than they are shown a picture of the earth from the moon and they have to discuss by digalo what they see (the question that appears in the Digalo - is it day or night in the picture?). Two more pictures are presented to the students, showing astronauts on the moon, and the students are discussing the second question again on the Digalo.

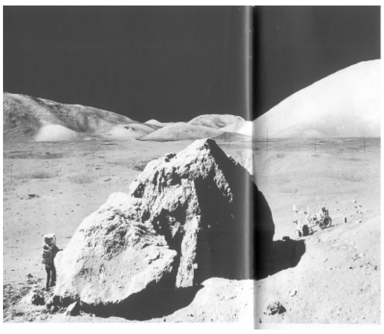
The formative assessment includes both pre and post questionnaires, , and observation notes. All lessons are videotaped and the videotaped findings are analyzed. In addition, students fill out pre and post questionnaires and the differences between their responses are assessed.

The summative assessment includes the pre-post questionnaires that the students fill in before and after the activity. The questionnaires include questions on the subject of day and night, in order to later check whether advancement was achieved in the concept of day and night.

The evaluation uses videotaping and analyzing the videotaped results, as well as an analysis of Digalo maps.

The teacher's role is to mediate the discussion by asking relevant questions, encouraging elaboration of explanations and supporting the computerized discussion. The teacher has to pose questions, correct students' mistakes, help students with the experimentation and lead the reflection following the discussions.

4.4.7 A thinking journey to the Day and night cycle: A computerized model of the moon phases (Israel)



This case is intended for enabling students to understand the day-night cycle and its relations to the movement of the moon around the earth. The case is based on a work of Schur and Galili (Schur and Galili, 2007) done with a computerized model of the moon revolving around the Earth and enabling the students to experience this movement from a variety of perspectives along the Thinking Journey mode of instruction. concepts of day and night on earth and moon, while comparing student use of different types of evidence. The activity uses a computerized model showing the phases of the movement of the moon around the Earth, as they change pictures of the earth and the moon that are the basis for enabling students to put themselves in specific places on the moon and on earth and to experience the relations between the movement of both celestial objects and the day-night cycle on both of them., and, in order to create a virtual journey, in which students learn the concepts of day and night.

Students are asked in this case to describe different environments on the earth and on the moon. They are asked to explain what they see, predict future events, and decide on the existence or absence of day and night in different pictures that are presented to them. understand the dynamic nature of the day-night cycle and the differences between the perspectives of the earth and the moon in relation to the changes of day and night and their connections to the movements of the earth and the moon that the students see in the computerized model.

The case duration is 4 encounters of 2 hours each. It is intended for 8th grade.

In their work, students use Digalo, Power Point, A computerized model of the phases of the moon, a workbook and a manual .The manual includes a framework story about an astronaut who wishes to understand if day and night are the same on earth and on the moon. Students receive the story line, instructions and the pictures.

The work is arranged, if possible, in 4 groups of 4 students each.

Students first watch a computerized model of he phases of the moon. Then they are shown a couple of pictures of specific places on the Moon and the earth and are asked to decide whether these pictures show day or night, to describe what they see and predict future events connections between the specific place of the moon and earth in the model and the existence of day or night upon these specific places. Discussions are made by the the use of Digalo.

Some of the Misconceptions regard the notion that day and night occurs only on earth which is dominant in determining the day and night also on other celestial objects like the moon. Many students think that the moon does not revolve around itself. Some of the fallacies immerge from the egocentric point of view of the students. The use of the combination of the computerized model and the Thinking Journey mediation with pictures enables students to experience the day-night cycle from a new point of view and to understand its dynamic nature.

The formative assessment includes developing the subparagraphs, and observation notes. All lessons are videotaped and the videotaped findings are analyzed.

The summative assessment includes a questionnaire that the students fill out before and after the activity. The questionnaire includes questions on the subject of day and night, in order to later check whether advancement was achieved in the concept of day and night.
The evaluation uses videotaping and analyzing the videotaped results, as well as an analysis of Digalo maps .

The teacher's role is to mediate the discussion by asking relevant questions, encouraging elaboration of explanations and supporting the computerized discussion. The teacher has to pose questions, correct students' mistakes, help students with the experimentation and lead the reflection following the discussions.

4.4.8 Storm (Switzerland)

This case concerns a weather issue – the storm. Throughout several sessions, the pupils work individually, and in small groups. They are invited to develop an enquiry approach in finding answers to some scientific questions that concern storm, looking for arguments from textual resources and defending their points of view during the argumentative phase.

The target population is pupils in primary school (around 9-10 years old, male and female; but it can also fit for secondary school pupils) and the estimated required duration of carrying it out is 2-3 sessions (45 minutes each).

The objectives of the case include improvement of pupils' vocabulary about the storm phenomenon, identification of the main features of a storm and its temporality; they also include improving the understanding of the characteristic of a lightning and how to distinguish between clouds. One of the objectives, that doesn't relate especially to the subject domain, is to better know how to extract information from texts. The case aims also to lead pupils to confront different understandings on a same phenomenon (storm in this case) and lead them to justify their position.

During the case, students use texts about storms (extracts of scientific literature for children).

The main steps in carrying out the case:

1. In the classroom each pupil gives answers individually; their responses give an overview about their pre conceptions about this phenomenon.
2. In classroom presentation of some main features about the storm; in class or at home, individually or in group, they read texts about storms.
3. In small groups around a table the pupils prepare arguments.
4. In groups, a debate with Digalo is taking place around an open question like for instance "are lightning touching the ground?".
5. Plenary discussion and feedback.

To use the case properly there has to be two rooms or spaces for group work and computers (at least 3: 1 server and 1 for each group).
The pupils' work is assessed by individual pretest and post test and by the argumentative maps they use through digalo. The evaluation is done by plenary discussion and by taping (groups discussion during the preparation of arguments (argumentative map) and oral debate / Digalo

The role of the teacher is to moderate, i.e. to provide information, synthesize, reformulate, give necessary words, ask questions, etc.

ESCALATE: The White Book

Part IV: The description of the respective implementations and lessons learned (France, England, Greece, Switzerland & Italy, and Israel)

ESCALATE: The White Book

Chapter 5: Description of the experimentation in France

Learning through argumentation and inquiry-oriented teaching: examples in Grades 3, 4 and 5 in

V. Tartas and V. Frède

Table of Contents

5.1 General backgrounds

Two aspects will be defined as general backgrounds in this section:

(1) Firstly, the general background of teacher training in France through the institute called IUFM. A brief description of this institute and its organization is described in order to clarify the context of teacher training and the possibility we encountered to integrate such training.

(2) Secondly, the subject under study we chose is astronomy so we expose the different reasons about this choice in terms of backgrounds: (a) the regional interest for aeronautics and space and the presence of the scientific museum specialized in astronomy and space "the Cité de l'Espace"; (b) the curriculum of elementary school in France and (c) the interest for Astronomy from a psychological point of view.

5.1.1. National and institutional context of the teacher training: IUFM and teacher training

IUFM (Institute of teacher training called Institut Universitaire de Formation des Maîtres) in Toulouse is an institute that is charged for pre-service and in-service teacher's training. It belongs to the 31 IUFM institutes in France that were created in 1990 in a will to join elementary school teachers and secondary school teachers in the same institute. Since that date, students all need a "licence" degree before beginning the training program in IUFM. There is a selection test to enter the first year of IUFM. The IUFM institutes are actually independent structures but are going to be integrated to universities in 2008. The IUFM of Toulouse will be integrated to University of Toulouse-Le-Mirail.

Pre-service training

The pre-service training is organized in two years.

The first year is devoted to teach students the relevant amount of knowledge they need to master to pass their examination. The success to that examination at the end of the first training year is a necessary condition to be able to become a teacher. In this context of examination training, no hour can be delivered to other activities than academic knowledge and thus there is no time for science activities using Digalo and argumentation for example. In this situation it was impossible for us to enter in such a training program with the Escalate project.

The second year is a sort of pre-professionalisation year where students learn the job keys and are taught some professional gestures. More precisely, they learn how to build a pedagogical sequence and how to teach in different situations, levels and contexts. The pre-service teachers are going regularly to school in order to train themselves to teach and to adapt their practice. They also have the opportunity to observe how expert teachers do. In the general training program devoted to the academic matters (French, mathematics, science…), it was impossible to add some Digalo activities because of the very limited number of training hours available. Nevertheless, it was possible for us to propose such activities consideration in the context of the pedagogical projects. Indeed, during their second training year, pre-service teachers have to present a project about a subject of their choice, have to implement this project in a class and then write a document (dissertation) about that experiment in class. In this context, we have contacted trainers responsible for the choice of the projects subjects in May and June 2006. We have written a short document to present the context of the Escalate project to the students in the beginning of

the university year (2006/2007). The science trainers were very interested in the subject we proposed and we talked about the possibility to co-supervise pedagogical projects on Digalo/ argumentation and microworld/inquiry in science. For instance, we wrote the following subjects:
-How can social interactions between students help knowledge acquisition in science?
-What is the role of argumentation in scientific knowledge acquisition? (for instance comparison of the same activity realized with or without a debate or between a Digalo form versus a paper/pencil debate)
- What is the role of argumentative writing in the science knowledge acquisition (in biology, physics, astronomy…)
-What is the impact of the different learning forms and their temporal organization (individual work/collective work) on the acquisition of a specific scientific concept?

They were presented to the students in October 2006 but in fact because of new and unexpected institutional guidelines from school inspectors, typical or more classical subjects were exposed to students as the ones they should better take in order to validate their training year. Unfortunately, Digalo-based science orientations were not enough in an academic direction to be chosen by the students this year. Moreover, the science subjects are not the most appreciated by the students themselves. Depending of the political choices that will be made next year, and the interest in science subjects students will have, we expect to be able to have some students choosing subjects to perform experiment on Digalo, argumentation and microworld in science in their class during their pre-service second year of IUFM for the university year 2007/2008.

In-service training

Teachers can follow in-service trainings in the IUFM since 1998. They can register each year to trainings that are presented in an academic plan that is decided in March of the year preceding the trainings. There were several theoretical possibilities for us to implement our project in in-service training, for instance with secondary science teachers (through science axis), with secondary French teachers (through argumentation axis), with elementary school teachers and also with all kind of teachers through the hypermedia tool axis. We were expecting to propose such training programs around the use of Digalo, argumentation, microworld in science since March 2006. For the first year (2005-2006) this was not possible because the dead line for presenting the programs was already passed (March 2005). For the second year (2006-2007) of the project, before the dead line (March 2006) we have organized meetings with the involved in-service trainers in IUFM. We have then exposed our projects through the different axis: science, argumentation, hypermedia tool…. Unfortunately in order to be able to be presented to the academic plan, the activities must already have been implemented and have results to show. In fact, they explained to us there was a necessity to have already concrete data and observations because those observations had to be presented to in-service teachers during the training program around Digalo for instance : how children really learn from Digalo session, how was it used, what are the recommendations to use it in class, the limits etc… Without some concrete examples of such a tool (Digalo and/or Microworld) use, they could not propose our training in the academic plan even if they were very interested. The in-service trainings can't be devoted to theoretical aspects only. The duration of the project has offered us some concrete examples of the use of Digalo and argumentation in science for elementary school children (more precisely in astronomy from grade 3 to grade 5). So now results and evaluation in class are available and we could envisage proposing an in-service training for the academic plan of the following year 2008 or the years after.

Because of all those difficulties and obstacles at this stage of the project (the first nine months of Escalate project) to enter in the academic teachers pre and in-service training to work on Digalo, microworld, and argumentation in science from IUFM and as it was impossible to contact some interested teachers from this ways, we decided to contact in-service teachers individually and directly in their schools and to find a group of teachers interested in such a project to be implemented in their class. One teacher could be contacted thanks to the space museum “La Cité de l’Espace” because she works for half time in the museum. She teaches in grade 3 in a school in Blagnac, in the suburbs of Toulouse. The three other teachers (one in grade 3, one in grade 4 and one in grade 5 all in the same school in Castelmaurou a small village near Toulouse) had already worked with one of the researcher of our team for another project in science and manifested again a real interest to be involved in this new innovative program. They were all interested in astronomy and more generally in science and in the inquiry-based approach of science. They were also interested in the role of discursive practices in learning and in particular argumentative activities. So we conducted during the first year of the Escalate project an implementation in elementary school in four different classes in science and more especially in astronomy. During the second year we pursue the implementation in the grade 3 with another case.

5.1.2. Astronomy as a situated scientific object under study by UTM

The main reasons of developing pedagogical cases in astronomy in the Escalate Project were oriented by two aspects: the first one relied on the historical and social contexts of interests of the region and of professional activities developed in Toulouse, mainly the fact that Toulouse is the European capital of aeronautics, and the second one that reinforced the choice done for the first reason was decided when a new researcher, specialist in Astronomy, integrated our research team in September 2005. Moreover, the French curriculum specifies that astronomical concepts such as the rotation of the Earth on itself and around the Sun in order to develop a scientific explanation of the night and day cycle and the seasons on the Earth are competencies that had to be taught and learned from Grade 3 to Grade 5. So the choice of this topic is situated because of the institutional, historical and social contexts and it arises also question very interesting to study from a psychological point of view. These points are developed in the following parts.

a) Toulouse: the cradle of the aeronautic and astronomical sciences

What may surprise visitors as well as professionals who come and work in Toulouse is the fact that there are a lot of activities around aeronautics and astronomy. These interests for these particular topics are grounded in the history of Toulouse that is the European capital of aeronautics. From 1919 when the first flight from Toulouse (France) to Rabat (Morocco), via the important role played by the “Aeropostale”, the French airmail service (from which very well-known pilots such as Mermoz or Saint-Exupery worked) which allowed to develop the aviation to the sixties where several engineers school in aeronautics and space settled down in Toulouse, there was and there is still this focus turned around the space and the aviation. Moreover, this interest not only comes from the industries but also the educational context is oriented towards such a topic and more particularly thanks to the scientific museum La Cité de l’Espace which opened in 1997 and proposes specific scientific attractions around the Planets, the space conquest… It proposes to families as well as schools visits which can be designed regarding the teachers 'activities in Physics or astronomy. The activities which can be realized at the Cité de l'Espace are numerous and various (we propose to the reader to go directly to visit the website www. www.cite-espace.com). We will only present here what we used with the pupils in elementary schools who participated in the Escalate Project. When the project began and after the first kick-off meeting, we contact the responsible of the educative activities in the Cité in order to know if there would be some opportunities to work in collaboration in astronomy. The responsible was very interested in the Escalate project and mainly on the argumentative aspects of learning science. After several informal meetings about the project' aims and the presentation of Digalo tool, the responsible introduced us to a teacher who worked half time in the Cité and half time in a school in Grade 3. And from March 2006, we conducted regular meetings with this teacher at the Cite de l'Espace in order to co-construct the cases in astronomy and preparing the implementation. We first worked on a first case "the seasons" case collaboratively and realized then the implementation in her class and in three other classes (among with two came at the Cité with their teacher). Then, we chose to implement the third one "the night and day" case because this year (2006-2007) the pupils in class did not have yet received lessons on astronomy so it was more relevant to begin with the movement of rotation of the Earth in order to understand why there are night and day rather than beginning with the seasons which implies more knowledge on the movements of the Earth. The Cité de l'Espace played in fact several roles:

- the first one is to offer us a kind of "laboratory" in which we could observe pupils in the workshop the Cite offers. It allowed us to understand and observe how a teacher-animator offers the pupils different tools to try to represent and understand how the Earth and other planets move and function. It was very interesting to first observe such a context in order to study the questions asked by the students, their interests and difficulties regarding such a topic; we observed several workshops before co-constructing the case with the teacher.
- the second one is the fact that the teacher who we work in the Cité has the possibility to meet us and develop with us different cases. In a sense, working at the Cité offers her the necessary "space" for collaboration and for construction of innovative scenarios. Moreover working in this scientific Museum is also an advantage as you are in a dynamic of reflection and creation of scientific activities.
- the third one concerns the fact that it offers the possibility to the teachers involved in the Project (but not only) to do astronomy differently with their pupils than they did in class. So it allows the pupils and the teachers another way of practicing astronomical science as it offers materials and tools (such as modeling of the Earth, the Moon and the Sun…) that are not available in school. Moreover the teachers in elementary school are "generalist" teacher in the sense that they are not always specialists of a science content (they just have a Licence degree level at university but either in French language or in philosophy or in Mathematics but not always in physical sciences or biology), so they can find here specialists of the astronomical science who are not embarrassed by the students' questions.

(b) Astronomy in the French curriculum of elementary school

In France, the astronomical lessons begin in Grade 3 according to the official curriculum. It explains that the pupils in grades 3, 4 and 5 has to be able to represent the apparent trajectory of the sun in the sky and its evolution during the year (knowing that it is shorter in the winter Solstice (the sun is down at the horizon) and the longer in the summer Solstice (the sun is higher in the sky). The pupils may know that, from the North Hemisphere, the trajectory is from left to right for an observer turned towards the sun. The pupils have to be able to use a calendar in order to determine the seasons, their main characteristics and their date. They have to know about the rotation of the earth on itself in one day and the revolution around the sun in 365 days and 6 hours. It is noticed that at elementary school the teacher is not obliged to give the information about the tilt of the Earth to explain the season (see p.25 and p26- from French official program for elementary school).

(c) Astronomy from the developmental psychology and psychology of learning

Understanding the movements of Planets and stars or more generally, the development of conceptual understandings of various astronomical phenomena that require a change in frame of reference is an interesting area of research from both developmental psychology and psychology of learning.
In developmental psychology the problem of frame of reference has been studied by different scholars from various theoretical perspectives (i.e. for spatial cognition Gestalt, Piaget; from a language and cognition perspective Sapir-Whorf hypothesis and Levinson today…). Several studies have been conducted on the representations of the Earth, its form and moves and disagreements are numerous about the way to access to the elementary children's first conceptions (see for example divergences between Vosniadou et al. (2005), Shoultz et al. (2001); Vosniadou et al. (2004) *vs* Siegal et al. (2004)). Moreover educational studies have reported on the difficulty that students have in developing understandings of astronomy (see for example Barnett & Morran, 2002). Students have contrary explanations of scientific phenomenon that are in conflict with the scientific explanation currently accepted by the scientific communities. Even elementary teachers held alternative frameworks in regard to the causes of the Earth seasons (Atwood & Atwood, 1996). The difficulties encountered by people rely mainly on the fact that their understanding comes from one perspective- the Earth's one. Consequently, developing learning activities that afford students the opportunities to confront their viewpoint to each other, to try to examine astronomical phenomena from different perspectives open avenues for new research investigation. The work presented here had this general aim, showing how a learning activity relying on argumentation and inquiry based approach can sustain and support change in both doing science and constructing new concepts in elementary school.

5.2 Description of the social context of the implementation

5.2.1. General description

We worked with two different schools and four teachers as already presented. We first contacted the teachers and presented them the project in order to know if they would like to collaborate. After giving us their viewpoint about the possibility of meetings and working together, about the material conditions too (are the computers of the school sufficient to install Digalo…), we decided to begin the research plan and to enter into practical and necessary steps to enter into this plan. In order to be allowed to conduct a research in school, you have to contact both the school inspectors who are in charge of the district where the schools are situated and the director of the school. If they give you their agreement, the research can begin. The other step is to get the authorization of the pupils' parents to participate to the Escalate Project and to be videotaped. The pupils whose parents did not give their authorization were not videotaped. As we were authorized in both schools, we began the collaboration work between us as researchers who were interested to observe their practices in science teaching and them, the teachers in elementary school who were interested in this project. The teachers are voluntaries and unpaid to participate in the project. Their motivation was very different. The teacher of grade 5 for example, Eloi[1], is fond of computers and science. He is very curious and interested in everything about the computers. Moreover he is responsible of the computers workshops in his school and he has constructed the computer room thanks to some computer gifts of some pupils' parents. The teacher of grade 4, Sonia was not really interested at the beginning in the project but felt engaged as her colleagues were motivated, her interest and engagement developed in the course of the project. The teacher of Grade 3, Florian was enthusiast to participate as he is engaged in several voluntary activities and he is interested in social science research. The other teacher of Grade 3, Martine, who works also at the Cité de l'Espace was very motivated as developed above.

The implementations were conducted from a direct contact with the in-service teachers in their schools. We worked with 4 teachers. We met the teachers at different levels of the implementation:

1) Initially in order to present them the Escalate project
2) Previously to the implementation in order to co-construct the cases, to build questionnaires for the children, to discuss about the sequencing of the different activities of the pedagogical scenarios. Some exchanges were also performed by emails concerning the shared of different scientific resources (scientific documents, website about teaching astronomy in elementary school (for example www.lamap.fr, etc…).
3) During the implementation through an interactive process, to adapt and transform the cases depending on the conditions (slates instead of computer...., working on the argumentative map realized by the pupils rather than entering in a modeling activity in the Grade 5, programming a visit to the Cite de l'Espace at the end of the activity)

We will explain more precisely those steps for each school we worked with.

5.2.2. Specific description of the social context of implementations in two different schools

Contact phase

We first contacted by phone and email the header of the school and some of the teachers we had already worked with for another project, in order to present the Escalate project and to ask for a meeting if some of them thought they could be interested in.

Teachers of the school in Castelmaurou were thus presented the project during their free

[1] The first names have been changed to preserve anonymity.

time after class. After some emails exchanges about our project, we went to that school in March 2006 and present it more precisely to the interested teachers. At the end, three of them agreed to implement the project about argumentation and inquiry based approach in their class since May 2006. An official authorization was solicited from the inspector of the school area who, after evaluation of our project, gave it to the director of the school. Then we were allowed to collaborate with the teachers on the project and to enter in their classes to observe how the teaching sequences go. The subject chosen for the presentation of the project (Astronomy) appeared to be a relevant subject for the three classes in this school. Indeed, even if we explained to teachers that astronomy was an example and it was possible to work and develop another scientific topic in the context of the project, they all agreed to focus on astronomical subjects. The teachers were volunteers in that sense that they received no money for their contribution.

Teacher Training or collaboration between teacher and researcher

About Cases construction

When we first realized these implementations in school (between April and June 2006) the microworld about the Earth and sun was not ready so we did not use it in these implementation that the reason why we concentrated our co-construction around argumentation and inquiry based approach around Digalo and the modeling activity without relying on the microworld.

<u>Implementation “seasons” in the two Schools:</u>

The implementation of the case “seasons” has consisted of a co-construction phase of work with the teachers. We wanted to co-construct a case based, on the one hand, on our “hypotheses” as learning researchers (the case must be adapted to develop phased activities with both collective and small group work, with argumentation and inquiry-based activities) and on the other hand, this case had to be coherent with the scripts the teachers are used to develop with their class. Indeed, the collaboration acted to develop complete cases in terms of learning goals, class organization (individual, small groups, collective phases), and evaluation. We initially discussed on three ideas of cases: night and day, seasons and moon phases. It was decided collectively that the case season was the most appropriate to be developed simultaneously in the three grades. The main reasons were because some of the children had already worked on the night and day concept and that seasons could be apprehended by all the children in various levels of argumentation depending on the grades and the familiarity to computers.
More precisely, the co-construction of the cases begins with the description of a global case structure that could be adapted depending on the classes and the uses and methods of each teacher:
-begin with a controversial question
-individual and collective answers, establishing hypothesis, trying to improve it by the facts…
-inquiry approach (observations, modeling, documents, microworld, and visit to museum….)
-Argumentative activity, debate (oral and with Digalo) in order to confront hypothesis
It was decided with the teachers that the duration of each working sequence would be around 45 to 60 minutes.

It was also decided that during the sequences, our role would be an observer-researcher's one in the back of the classroom except during the Digalo session where the teacher won't be in the computer room as the class is divided by two groups when the pupils went to the computer room as there is not enough computers for all the class and they were working by small groups of two. So the teacher stayed with half of the class whereas the other half went with the researchers in the computer room.

The adaptation of the case structure to each class was conducted in collaboration with each teacher. We thus meet either by email and at school, each of the teacher and in collaboration, we wrote a pedagogical sequence including all the phases of the case and the social organization and tools expected. The real implementation for each class is described in part 4. When all this preparatory work was finished, we began the implementations in class in May 2006. After each sequence, a brief discussion with the teacher was organized in order to adapt or adjust the sequence if necessary.

Implementation "night and day": in one school and in Grade 3

The process is the same as the one described for the season case implementation. And this night and day case was implemented from December 2006 to March 2007.

About Digalo Uses

We presented the uses of Digalo to the teachers relying on the previous experiments we had with the Digalo tool as one of us had already used it in a previous European Project called Dunes. So we used these previous experiences in order to present the different contexts of uses of Digalo. We did not really "train" teachers to Digalo use. Indeed, we presented to each teacher briefly how Digalo works and how it could be used with children. When the Digalo activities were implemented in classes, we had previously prepared some maps with children names and initial questions about astronomy and we were with the children during the activity. In order to prepare the map with the introductive question initiating the debate through Digalo, we discuss with the teacher in order to well initiate the debate. For example, we had a lot of discussions about the way of formulating the initial question. Is it better to use a question that has been proposed by one of the group of pupils before or is it better to be a more general question formulated by the teacher with his/her words? Is it always a question? Can it be an assumption proposed by the pupils in a previous phase of the sequencing activities that the pupils have to discuss and judge as a scientific or not scientific explanation of the phenomena under study? According to the teachers and to the previous steps in the sequencing of the activities we decided to use the different assumptions formulated by the pupils in small group in class before the Digalo session. So there is not always the same initial question on the map even if the pupils worked on the same topic in the three different levels as the small group of pupils sometimes did not reach the same assumptions.

The teacher was not present with us during the Digalo session. He/she was with the rest of the class that was not on computers. Then during the activity itself, we first explained how Digalo worked to children and helped them using it all along the session. We proposed them a phase of familiarization of the Digalo tool on a topic chosen by the teacher and us. After this phase of familiarizing and testing the tool, we develop the Digalo session on the astronomical topic. Sometimes, when it was possible, to make the debate going on, we played a role of moderator in Digalo.

The training with the teachers is more or less a co-constructive activity between the teachers and the researchers where we co-constructed the case taking into account on the one hand, the specificity of the Escalate project (that is to say both on argumentation and inquiry based approach, the idea of creating an opportunity to learn science through an activity that looks like the one develops by a researcher: to begin with a question and to develop an experimental approach : constructing an hypothesis, tying to improve it in the light of facts that would be constructed) and on the other hand the teachers' teaching habits and practices who accept to join the project (we will develop a bit more when we will present the different case studies in the results part).

5.2.3. Artifacts used

We have used several kinds of artifacts that are playing different role in the learning process. Three particular artifacts are used:

1. **"Argumentative" artifacts**: The Digalo software, the Digalo products (argumentative map printed) or argumentative discourse on paper/pencil/slates …

We used the Digalo software in order to make children construct argumentative maps from a controversial question in astronomy. The computers were used in two ways. In the first implementation, children were grouped by 2 or 3 in front of a computer and had to collaborate to choose and write their arguments. They were in communication with a group of 2 or 3 children on another computer in the other part of the room. In the second implementation, the work was done individually. Indeed, children were put alone in front of a computer. Each child was in communication with 2 or 3 others that were also alone in front of a computer. It appeared that computer used was quite easy with the children mainly for grade 5 because the majority of them have a computer at home and are used to write on MSN. The Digalo tool was always used in this way: we wrote on the screen an initial question or an initial argument that came from what children had said during the initial debate in class. So we used already filled maps to begin the argumentative activity. We used slates for argumentation during the first implementation of our season case in grade 3. The choice to use the slates was done because the computers were out of order. We had initially planned to work with children on Digalo but as this was not possible, we decided with the teacher to change the activity from the point of view of the artifacts. The argumentative activity was performed but instead of a screen, children wrote their hypothesis, arguments, and ideas to the others on their slates.

We used also the printed maps obtained after a Digalo session, in order to make children think back about their arguments (In grade 3 and 4). In grade 5, the teacher added an activity on argumentation itself by looking with the children if the maps were argumentative ones or not.

=>Such argumentative maps after they were creating through Digalo have been used as artifact to create a reflection on the levels of explanation given by the different group or pupil. It is used with the assumption that it (this already created map) may support the analysis of the process of doing science itself…

2. **"Inquiry artifacts":** microworlds, modeling, and experimental process (through or not "cahiers d'expériences" that is to say sort of science notebook)…

In order to construct an inquiry-based approach several artifacts have been used.

We first had planned to use a microworld, designed for our astronomy case but in fact because of the difficulty to use and understand it for elementary school children and the short time we had, it was impossible to use that artifact during the project. We expect to use it later in the context of pre-service and in-service teachers training but also by adapting our cases for secondary school students. But modeling has been used.

Modeling artifacts have been used in two different ways:

- "already" modeling design have been sometimes used in class by the teacher to explain the astronomical phenomena or by the children at the Cité de l'Espace for example. In the museum children could use modeling tools: mainly about night and day, moon phases and seasons. There are tools where children can manipulate the celestial bodies in order to understand how the mechanics works. For instance, for the moon phases, children put their head in a sphere that represents the Earth (see figure 1), a light is fixed and they can move a ball representing the moon all around their head and observe the different moon phases. For the seasons, they can move the earth around a light (modeling the Sun) and observe how the tilt of the rotation axis induces lightening change between the two hemispheres and for the same hemisphere depending on the season (see figure 2).

Figure 1: Using the model of phases of the moon at the Cité

Figure 2: Using an artifact of seasons at the Cité

- Modeling Artifact “in progress” (materials to be constructed such as a lamp with a sphere in order to explain night and day or seasons). Designing model has been a scientific activity that has been developed by one teacher and in the workshop at the Cité de l’Espace. For the modeling (performed in grade 3 for the seasons case implementation) teacher and pupils used globes, balls and lights in order to model the seasons on Earth and the tilt of the rotation axis.

Figure 3: modeling activity in Grade 3 in the school Blagnac.

Figure 4: example of Digalo map interactions in Grade 4.

Figure 5: teacher presenting the rebuilt map to the classroom in Grade 5.

The experimental process seen as a routine procedure to get familiar with scientific productions have been taught by the teacher through or not “cahiers d’expériences” (in Charpak’s initiative to teach science in elementary school, La Main à la Pâte) according to each teacher’s practices.

3. Scientific texts and documents

Some written documents were used during the small groups activities: a calendar with a table including the times of sun rise and sun set all along the year; documents with temperatures in different countries (northern and southern hemispheres); documents with the distance between the sun and the Earth depending on the seasons; documents to help children add in the time system in base 60. During all those activities, children could write their observation, conclusion on a piece of paper.

5.3 Description of the course of the activities themselves

We decided to develop four cases related to the program « the sky and the Earth » of the french elementary school curriculum. More precisely we were interested in:

-the night and day cycle
-the seasons on Earth

- the phases of the moon
- the history of science (see chapter 4 for a description of these four scenarii).

We have up to now implemented two cases, one about seasons in the first year of the project and one about night and day the second year of the project. The two others cases have been designed in a theoretical way and are ready to be implemented in the class in the same way.

All thoses cases resulted from a choice of working in the context of relativity of movement and referential frames in astronomy that appeared to us very relevant to use with Digalo and microworld. Indeed our three first cases were designed to favour argumentation about “what can I see or feel from the earth?”, “what could I see from another location in space?” “How can I explain what I see on earth from different points of views?...etc..” The last case about the history of science was designed to illustrate that this discussion on the relativity of referential frames has already been made by scientists before and is a way to understand astronomical movements. More other as we were initially interested in using the microworld, it appeared also that entering the situation from the relativity of referentials was relevant for the astronomical questions that were given : indeed in the microworld children can change his location and look at the sun/earth/moon system from the earth, from the moon, from the sun...

Each of the designed case was integrated in a pedagogical sequence in collaboration with the teachers of the various classes depending on their students’ abilities and on the prerequisite knowledge they had. We will describe briefly each of these cases and then explain how they were integrated in a pedagogical scenario with the help of the teachers.

1) The season case deals with the explanation of the reasons why there are seasons on earth and the reason why it is hotter in summer than in winter. The seasons topic belongs to the curriculum of the elementary school and is usually explored in grade 4 or 5. The common misconception is to attribute the seasons to the varying distance between the sun and the earth.

2) The night and day case deals with the explanation of the night and day cycle. The common misconception is to explain night and day from a movement of the sun around the earth or a wrong movement of the earth. The night and day cycle is usually explored in grade 3 relatively to the curriculum and before the seasons consideration.

3) The phases of the moon is not explicitly present in the French curriculum but is linked to a part dedicated to the light. Indeed from grade 3 to grade 5 children are encouraged to observe the moon and then to find an explanation for the changing aspect of the moon during the month.

4) The history of science is designed to illustrate through historical texts the debate about heliocentric and geocentric systems for the solar system.

The case “seasons” was the first implemented one. It was implemented in three different grades of elementary schools and in four different classes (grade 3: 2 classes, grade 4: one class, grade 5: one class) during March and June 2006.

Our common goal was to explore the students’ first representations and drive them toward a scientific explanation of such a phenomenon. We expected that at the end of the sequences dedicated to this case, children would understand that the tilt of the Earth's axis is responsible for the variation of the length of day (night) during the year. We expected also that they could locate the position of Earth on its orbit with regard to the Sun according to the seasons. The case season was implemented and included in a pedagogical sequencing of activities in co-construction with the teachers. Ignoring the small differences between groups, we will first describe the general structure used. The case was divided theoretically into 9 main phases in agreement with the teachers' uses. We decided that the first phase would be devoted to a pre-test of the student knowledge on astronomy (the pre-test was a written one not only about seasons but also about other astronomical subjects like night and day and phases of the moon, it was constructed with the help of the teachers). The second phase would begin with controversial questions asked to the children in order to collect their initial conceptions about the phenomena. The pupils would have to answer to some questions individually about seasons on their workbook. For example, one of the questions could be: Why is it hotter in summer than in winter? Or Do the night and the day have always the same duration? The third phase would consist in small groups discussions in order to encourage debate, the discussion could be based on documents (the calendar for instance). Thanks to that phase, we thought that children would develop hypothesis and would confront them. The fourth phase would be devoted to a collective and oral presentation of the hypothesis that had emerged from each group, for instance they could be: The sun remains less time in the sky in winter; In winter there are too many clouds; The Earth rotates faster in winter than in summer; The Earth is closer to the sun in summer.... The fifth phase would be a familiarization to the tool Digalo on another case different from the season's one. Then the sixth phase would consist in a Digalo session on computers about questions related to seasons. The seventh phase would consist in discussion in small groups and then in collective way around the created Digalo maps obtained from phase 6. With the help of Digalo maps and the teacher, the different hypothesis could be discussed and examined from their plausibility. The eighth phase was thought as a modeling activity or a workshop in the museum (La Cité de l'Espace). The case ends with the ninth phase where a post-test with the same questionnaire would be given to the children.

We will describe briefly the various practical implementations of this case in the two schools we worked in.

The first school where we have implemented the season case was in Blagnac (a city near Toulouse) in a grade 3. In this class, the teacher is fond of astronomy; she works in her school as a teacher and also in the "Cité de l'Espace" as an animator in pedagogical workshops. The group was composed of 28 pupils that are 8-9 years old. The pedagogical scenario was implemented thanks to a co-construction with the teacher and integrated in a progression about science. It was organized precisely like that: after the pre-test questionnaire, the initial question proposed in class by the teacher was: "do the night and day have always the same duration?"

This question was first discussed in class in a collective debate animated by the teacher, then children were organized in small groups of 4 children and could use a calendar (with set and rise hours of the sun during the year) to evaluate the length of day and thus answer the question. The teacher of this class is used to make children work in small groups. The children agreed to answer "no" to that initial question relying on their calculations. In the following lesson, we went to the computer room without the teacher and explained to the children how to use Digalo in order to help them become familiar to the program, they had to discuss on a topic in science but not in astronomy. In the next sequence, the question "Why don't night and day have the same lenght?" was proposed and we had planned this activity on Digalo. But the Digalo session was impossible to conduct on that question as the internet connections were out of order at that time. In agreement with the teacher, we decided to replace the Digalo session by a "slate session" where children could write their arguments on their slates. It was organized in the classroom and conducted by the teacher. Several links to the season's concept and their characteristics appeared explicitly in children's arguments and hypotheses. A following sequence was devoted to a modeling activity in small groups where children had to try to understand why the seasons were not the same in the south and north hemisphere. They could use a light, a stick and a ball. Then this modeling activity was performed in the whole class with a globe and conducted by the teacher. The last sequence was devoted to the post-test questionnaire.

In the second school (Castelmaurou), we have also implemented three times the seasons' case. In grade 3, the teacher was very interested in the project because he has tried from the beginning of the year to propose various debates to his class. He was interested in the other form of debate through the use of Digalo that we were proposing. The children were thus used to debate in a collective way in class and to take into account the arguments of their pairs. There were 25 children aged 8-9 years old. We decided with the teachers to build a pedagogical sequence about season in that way: first the pre-test questionnaire was given. Then two following questions were chosen to be presented in class: "do the night and the day have always the same duration? What do you know about seasons? "The collective debate was organized and conducted by the teacher in a similar way children were used to. Then children went to work in small groups of 4 children and had the calendar document to help them answering the question. The familiarization phase was performed on Digalo by us. The Digalo session was then conducted with two children per computer. They had to discuss with two other children located on another computer about an initial question that we had already written on the screen. We choose to use three different initial questions or affirmation all related to seasons taken from children own arguments and hypothesis that had emerged from the collective initial debate. Then as the maps were quite poor in this class (few arguments in one map) we decided to build new maps. Those "reorganized" new maps were constructed from all the arguments we found on the real maps that we grouped and organized. The aim of this rebuilt is to propose to the students in one map different viewpoints regarding the same problem. In this sense, this new map is thus a reconstruction from the several different maps co-constructed by the students through Digalo. That it is not one map co-constructed by the students but a map that we –researchers- have rebuilt having in mind the fact that it is important that the students can confront different viewpoints on the same problem (a controversial question which can imply different explanations). The maps were printed and given to children in a following sequence in small groups' discussion. This step was followed by a collective debate where children tried to justify their ideas about the seasons. Then children went to the museum (La Cité de l'Espace) and attended a workshop on Earth, moon and sun system. Then they were given in class the post-test questionnaire. The visit to the museum was not initially planned but during the implementation of the case in the classroom, the idea to complete the case by a visit to the museum emerged from discussion between the teacher and us.

In grade 4, the class was composed of 23 children aged 9-10 years old. The implementation was conducted in exactly the same way than the grade 3 class, except that the post-test was given before the visit to the museum for this class.

In grade 5, there were 28 children aged 10-11 years old. The teacher was used to make the children play roles in debates. So they were used to argue a hypothesis even if they don't believe in it. They were used to conduct an argumentation. So this teacher was quite interested in observing how this could work in a different context using Digalo maps sessions. We decided to implement the case in his class by taking into account this aspect explicitly. Children had a lesson on astronomy at the beginning of the year but none of them could initially answer to the questions about seasons. The teacher was disappointed as he first thought that this question is too easy for his pupils as a lesson had been already given on such a subject. The implementation was similar to the other classes but the documents were slightly different. Indeed after a pre-test, the initial question was "Why is it hotter in summer than in winter?" it was discussed through a collective debate in class animated by the teacher. Then children were given documents (real distances Earth/Sun in winter and summer, temperatures in different countries) and worked in small groups of 4 children. It was followed again by a collective debate in class. Then, the familiarization to Digalo preceding the Digalo session we animated with the children was conducted. After the Digalo session, a discussion in class on some rebuilt maps was proposed. The teacher wanted the students to discuss not only on the validity of the arguments in the sense of science but also on the validity of the arguments in an argumentative sense: are there arguments, why etc..? This aspect of the case was not initially designed. Then this discussion continues in small groups and children were very interested in it. This was followed again by a collective debate in class focusing on the seasons where the tilt hypothesis emerged from the children themselves even if none of them had proposed this solution during the argumentative Digalo activity. The teacher was really happy from that. Then the post-test was given to children.

Concerning the small groups, the members of the groups were chosen from the pre-test results and with the agreement of the teachers. We decided to form groups with same level when it was possible: a group is composed by one "scientific answer" child, one "incoherent answer" and 2 "mixed answers"[2] children regarding their performance in the astronomical questionnaire (pre –test) in order to see how the interaction between children of various levels and sharing different arguments or hypothesis could organize a debate.

The case "Night and day" was implemented in the school of Blagnac since October 2006 with the same teacher working at the Cite de l'Espace but with new pupils (grade 3 in 2006/2007). We gave a pre-test to the children about night and day especially but also we left questions about seasons and moon phases. The questionnaire was made from the initial answers of the children to the question "why are there nights and days" and with the help of the teacher. Then children were familiarized to Digalo tool on a question relative to the compass that they had already discussed in class with the teacher. Thus the night and day case was integrated into a pedagogical longer sequence designed by the teacher about the "sky and the earth" curriculum. Then children went to museum and followed an exhibition devoted to night and day and seasons and phase of the moon mainly. They could use modeling tools in order to understand the phenomena and an

[2] For definitions and examples of each kinds of answers « scientific answer, mixed ones and incoherent ones" see details in part 6. Evaluation part.

animator explained them the different concepts. They could manipulate objects in an inquiry-based approach.

The following of the sequence co-constructed with the teacher will continue in class through debate about the night and day by using Digalo.

The answers to the pre test were examined in order to define some groups. We decided to change our group design and for this experiment to make groups of equal level. 2 groups of 4 children with good performance to questionnaire and similar conceptions about night and day, 2 groups with medium level and quite similar conceptions about night and day and 2 groups with bad level and similar conceptions about night and day. Those groups were formed with the help and agreement of the teacher. We are interested in seeing how the debate progresses in the case of children having the same kind of arguments and hypothesis at the beginning of the sequence.

5.4 Iterative processes to redesign the previous activities/cases

The case construction was obtained in a collaborative way since the initial design. Moreover in the course of the case implementation, we had to adapt it and to redesign some features always in collaboration with the teachers.

For instance, concerning the documents used in class and distributed to the children, we did not initially plan to use calendar but after the first sequence, we redesigned the case with the teacher in Blagnac by adding this activity based on calendar and length of the day computing.

Moreover, with grade 3 in Blagnac, we had planned to use Digalo maps on computers to make the children debate about the seasons. As the computers were broken, we did not abandon the debate but redesign the activity with an artifact that children were used to manipulate in class: the slates. Thus the debate on seasons and the written argumentation activity could be performed without the computer support. This will give us observations of debate and argumentative activity without Digalo.

In grade 3 and 4 in Castelmaurou, the case did not initially include the visit to the museum « La Cité de l’Espace » but during the course of the implementation, this sequence was added. For grade 3, it was added before the post test in order to give us data on the evolution of performance of the children after an argumentative activity on Digalo plus an informal activity in museum. In Grade 4 it was done after the post test because we did not want to take it into account for the children performance and see only the effect of an argumentative activity on Digalo. In grade 5, we did not plan to have a sequence dedicated to the discussion about the validity of the Digalo maps in terms of argumentation. But during the course of the implementation, it appeared that adding this aspect was very relevant with that class. It gave us data both on the argumentation about science but also about the way children understand the argumentative activity in itself.

Concerning the organization for the Digalo session, we begun with the choice of 2 or 3 children collaborating on a same computer and faced to a similar group of children for discussion on Digalo about seasons. Then we redesigned the case in terms of organization and choose to put only one child per computer for the night and day cycle.

5.5 Main observations

The main observations we made have all been videotaped in the different classes. The pedagogical session lasted from seven sessions to nine sessions of around 45 minutes each. One but sometimes two sessions by week have been proposed.

Implementation 1: 'seasons' case

- Grade 3 in School 1: April-June 2006: twenty eight nine years-old pupils. The particularity is that there is also another adult in the class who accompanied one child who has neurological problems. The pupils are mixed concerning their culture. Martine who is the teacher has responsibility of the class only two days by week and the other days they have another teacher. Martine is the teacher who works at the Cité de l'Espace. The first case implemented in this class was the "seasons" one. The pedagogical sequence through seven phases is described earlier (see 3. Description).
- Grade 3 in School 2: April-June 2006: twenty five nine years-old pupils. The pedagogical sequence consists of nine phases: from Pre-test Questionnaire to the Visit to the Cité de l'Espace (workshop on Earth, Moon and Sun system) during a day ending the sequence.
- Grade 4 in School 2: April-June 2006: twenty three 9-10 year old pupils. The pedagogical sequence consists of nine phases similar to the grade 3 of the same school as the two teachers had decided to make the same sessions and the same timing.
- Grade 5 in school 2: April-June 2006: twenty-eight 10-11 years-old pupils. The pedagogical sequence consists of nine phases similar to the two other levels except that this class did not visit the Cité at the end.

Implementation 2: night and day case

Grade 3 in school 1: December 2006 to March 2007 (The evaluation of this implementation will not be developed in WP5).

5.6 Evaluation: Studying the migration of students' explanations about the seasons through argumentation and research like processes of inquiry

The evaluation is conducted on several data:
- Students' performances at the pre-test and post-test questionnaires administrated before the argumentative and research-like processes of inquiry and after them.
- Collective debate in the class and small group's work on different materials (calendars, argumentative map and sometimes modeling) in class and in the museum for some classes. Here we plan to analyze conceptualization through discursive patterns.
- Collective maps through Digalo: claims, justification, counter-claims, reply will

be analyzed (which kinds of argumentative dynamics elementary school students can develop supported by this Escalate teaching-learning program?)
- Modeling activities: particular analyses will be conducted on the way children engage in such a scientific activity and the role of this activity in the process.
- Drawings, texts produced by children during the sessions.

We particularly focus our analysis on the migration of students' explanations of the seasons phenomenon (what are the first hypothesis made by the children and how do they develop through the different sessions) through a developmental perspective as we have implemented the same case in four classes and more particularly three different grades and within a same level during different kinds of activities. We would like to insist on the interpretation and construction of each teacher according to his/her own practices and from the point of view of the pupils what changes are between these levels in elementary school. Do they face the same difficulties in astronomy or not? Which kind? How the teachers take them into account? For what outcomes?

The analysis both quantitative and qualitative of students' oral and written productions is composed of two different parts:
- the first one develops the results for each grade of first intuitive explanations or theories and scientific knowledge students can work with before entering in Escalate program and after. That is to say we first develop the results of pre and post tests questionnaires for each level and compared them for each level and between the different levels. It allows to shed light on the different kinds of explanation elementary children can rely on to explain the seasons and how they evolve through the different argumentative and research like processes of inquiry activities.
- the second part consists of analyzing the kinds of argumentative dynamics occurring through the different activities. We focus more particularly on the argumentation Digalo-supported that is to say the analysis of the co-constructed maps by the students and the uses of the rebuilt maps in small group and collective class group debates. This analysis allows us to link kinds of knowledge or theories used by the students and argumentative dynamics supported this knowledge construction.

5.6.1. Elementary Students' first intuitive explanations and scientific knowledge used and their development through Escalate program

We describe here the main results concerning the data analysis obtained from the answers to the pre and post questionnaires of three observed classes in the school Castelmaurou. The corresponding grades are grades 3, 4 and 5.

Our goal is first of all to report the differences in terms of global performance to the questionnaire for the season's concept for each grade and for each step: before Escalate program about seasons and after it. Then we focus on the content of the answers given by children by separating the questionnaire into two main concepts: night and day cycle and seasons. We are interested in the students' "level of understanding" or level of explanation. How much do they know and how is this knowledge organised? The reason why we focus also on the night and day concept understanding relies on the fact that we believe, in a way, that learning about seasons gives information about the movements of the earth and thus can improve also the night and day understanding. Only the seasons will be developed and analysed here; the data analysis and results for the "night and day" concept are described in appendix 2.

In order to analyse the seasons answers, we propose different categories to classify children answers or level of explanation. The first and lower category that we call *incoherent* is attributed to children's explanations when they give for the same concept several answers that are incompatible or opposite. For instance a child who says that the seasons are due to the fact that the Earth has a varying distance to the sun and in a similar question who says that the Earth is not closer to the sun in summer will be classified in that category. The last and upper category is the *coherent scientific* one when the child gives answers that are expected and that are in coherence one with each other. For instance, we can consider that a child who says that the Earth does not have a varying distance to the sun for seasons and who says that it is false to pretend that the Earth is closer to the sun in summer is *coherent and scientific*. In between, we define other categories (*mainly scientific*, *mixed*, *mainly false* or *coherent but false*) depending on the number of pairs of questions considered. We will describe this precisely in the next paragraph.

The questionnaire is given in Appendix 1.

Seasons

From a quantitative analysis:
We give a score of 1 if the child gives a scientific (correct) answer and 0 for any other answers. We will thus measure the amount of knowledge related to the season's concept only (9 questions). We thus obtain a score out of 9.

Children in grade 5 obtained a mean score of 6.44 (SD= 1.847) at the pre test and 7.22 at the post test (SD=1.672). Children in grade 4 the mean score of 5.32 (SD=1.041) at the pre test and 6.27 (SD=1.518) at the post test. For grade 3, the means scores are respectively 6.04 (SD= 1.122) and 5.83 (SD=1.523). The mean scores have all increased from pre to post test except for grade 3 where it has decreased after instruction.

For each level we make a comparison between the scores for the pre-questionnaire and post-questionnaire. We remind that the post-questionnaire is given after the seven or eight argumentation and inquiry based sessions. There is a significant evolution from the pre to post-questionnaire ($t=2,75$; $p=0.01$) in Grade 5, but also in Grade 4 ($t=2.585$, $p=0.017$). In Grade 3, the difference is not significant. It means that for Grades 4 and 5, the effect of this particular Escalate program about seasons had a significant influence on the students' level of understanding about seasons but no effect in Grade 3.

Moreover, in a developmental perspective, we observe that there is a global significant difference between the mean scores of three groups in the pre-test ($F=3.683$, $p<0.03$). The Tuckey post hoc test shows that this difference occurs between Grades 4 and 5. Children of Grade 5 are significantly better than students in Grade 4 before instruction. At the post test, the differences are still significant ($F=5.026$, $p<0.009$) but it occurs now between Grade 3 and 5. Students in Grade 5 are significantly better than children in Grade 3 after instruction about seasons while they had the same level of understanding before instruction. We observe no difference for the global post-score between Grade 4 and the other two groups.

To summarize, those two statistical results highlight two main points: first of all the effect of the Escalate program on seasons understanding was relevant for Grades 4 and 5 only. Moreover children in grade 3 did not improve after such a teaching-learning program. Even if the difference is not significant there is a decrease in the global mean score for Grade 3. It seems that Digalo and inquiry based activities for Grade 3 students were not as relevant as for the two other grades to acquire knowledge about seasons. We indeed reported that children in Grade 3 had difficulties to use the computer and to write and were not as ease as the older elementary children. We can suppose that the level of the activities proposed is too far away from the actual level of the Grade 3 students, and it did not allow them to support their thinking and understanding of the season phenomenon.

From a qualitative analysis of pre and post questionnaires:
We are interested in classifying the level of understanding of each student into defined categories taking into account also the level of coherence of their explanations. Thus we have selected only questions that are not purely factual questions. For instance for the seasons concept, we did not take into account the question related to the duration of a season (question 8) because we considered that it was not relevant for the measure we wanted. Moreover we could not easily confront it to another similar question to look for coherence. Thus we kept only 6 questions. Each question has two possible answers: correct or false. We were interested into pairs of questions to define coherence. We grouped two questions about the distance (Q4 (**Indicate the correct drawing for the Earth's orbit)** and Q4 of the table (**In summer the Earth is closer to the Sun**). If the answers at these two independent questions are correct then the coding is *coherent and scientific* : "The Earth is not closer to the sun in summer". If the answers are "the Earth is closer to the sun and is not", the coding is *incoherence* because two opposite explanations about the same phenomenon are given. Eventually, if the two answers are "the Earth is closer to the sun" then the coding is *coherent but false*.

For the pairs of questions Q1 of the table (**The Earth revolves around the Sun in 24 hours**) and Q5 of the table (**The Earth revolves around the Sun in one year**). Similarly, if the answers are "the Earth revolves around the sun in one year and not in 24h" the coding is *coherent and scientific*. If the answers are "the Earth revolves around the Sun in 24h and in 1 year" the coding is *incoherent*. Then if the answers are "the Earth revolves around the sun in 24h and not in 1 year" it is *coherent but false*.

For the question Q2 of the table (**When it is winter in France, it is summer in Australia**) and Q6 of the table (**When it is summer in Toulouse (France), it is winter in Spain)**, the same method is applied and *coherent* is attributes to answers "seasons are not the same in opposite hemisphere and are the same in the same hemisphere". *Coherent but false* is attributed to the association of answers "the seasons are different in the same hemisphere and the same in opposite hemisphere". All other associations are *incoherent*, for instance: "the seasons are different both in the same hemisphere and in the opposite one".

We will give the results pair by pair and then by grouping all the data.

Pairs of questions

Q4Q4t : The distance characteristic

Progressing through Escalate activities has a benefit effect on Grades 4 and 5 where the percentage of correct association between the two answers increases but a negative effect on Grade 3 about the distance characteristics where it decreases in the post test. Nevertheless, it is only in grade 4 that the differences in the category repartition between pre and post test are significant (Chi^2=8.632, p=0.013). The main significant effect appears for the *coherent and scientific* category (from 0 to 27.3%). In the pre-test, there are differences between the groups (Chi^2=14.590, p=0.006) but no differences in the post-test. Those differences belong to the *coherent scientific* category where both Grade 3 and Grade 5 and significantly better than Grade 4 in the pre-test. Grade 5 students give more *scientific coherent* answers than the two other grades (see table 1) in the post-test but the differences are not significant. If we look grade per grade, no strong effect appears in Grade 3 between the categories. In Grade 4, there are significantly less *coherent* answers than the two others in the pre-test and in Grade 5 there are significantly more *coherent scientific* than *coherent but false* answers in the post-test.

Table 1: Q4Q4t : distance characteristic of season concept

	Grade 3		Grade 4		Grade 5	
	pretest	posttest	pre	post	pre	post
Incoherent	41.7	43.5	40.9	45.5	29.6	29.6
Coherent but false	16.7	30.4	59.1	27.3	40.7	22.2
Coherent scientific	41.7	26.1	0	27.3	29.6	48.1

Q1tQ5t: The revolution characteristic

We observe in table 2 that concerning the revolution of the Earth around the sun, the Grade 3 students are very performing in the pre-test. Indeed they reach 75% of correct answers after Escalate teaching-learning program and had already almost 70% before it. This score is higher than the one in Grade 5 where they have an important amount of *incoherent* answers (33.3%) in the post-test. It means that grade 5 students have, after Escalate program, answered both that the Earth revolves around the sun in one year and in 24h. In the pre-test, there are no significant differences between the groups. We observe a tendency in the post-test (Chi^2=8.732, p=0.068) between the three groups. There is a significant difference in the category repartition in the post-test between grades 3 and 5 (Chi^2=8.950, p=0.011). There are indeed more *incoherent* models and less *coherent but false* models in grade 5 than in grade 3 in the post-test.

If we look grade per grade, we observe that for each grade, there are significantly more *coherent and scientific* models in the post-test than the other two models. It was already the same in the pre-test for grades 3 and 5.

Table 2: Q1tQ5t: revolution characteristic of season concept

	Grade 3		Grade 4		Grade 5	
	pretest	posttest	pre	post	pre	post
Incoherent	17.4	4.2	36.4	22.7	14.8	33.3
Coherent but false	13	20.8	9.1	13.6	14.8	3.7
Coherent scientific	69.6	75	54.5	63.6	70.4	63

Q2tQ6t: The hemispheric characteristic

Table 3 shows the repartition of pairs of answers about the hemispheric differences. This association gives mainly good results since pre-test. In post test for grade 4 and 5, more than 80% of the children have a coherent view of the hemispheric properties of seasons. The incoherence observed in grade 3 could come from the fact that they don't situate very well the two proposed countries relatively to their city. Nevertheless, Spain is much closed to Toulouse so this remark might have a slight effect on results. There is no significant difference nor between the tests nor between the groups. For each grades, both in the pre and post tests, there are significantly more *scientific* answers than the two other categories. Nevertheless, we don't observe any significant developmental effect for this question.

Table 3: Q2tQ6t: hemispheric characteristics of seasons

	Grade 3		Grade 4		Grade 5	
	pretest	posttest	pre	post	pre	post
Incoherent	33.3	33.3	27.3	18.2	11.1	14.8
Coherent but false	0	4.2	4.5	0	0	3.7
Coherent scientific	66.7	62.5	68.2	81.8	88.9	81.5

Globally on the 6 selected questions

Amount of knowledge

If we look at the amount of knowledge grade per grade from pre test to post test, we obtain on the 6 selected questions about seasons the following scores (we remind that the scores are obtained from the attribution of one point to each correct answer and 0 for any other answer):

For grade 5 the pre-test score is 4.30 and reaches 4.63 in the post-test. The difference is not significant. For grade 4, the scores are 3.5 in the pre-test and 4.18 in the post-test. The difference for grade 4 between the two tests is significant ($t=2.56$ $p=0.018$). For grade 3, the scores are respectively 4.25 and 3.92 in the pre and post-tests. The amount of knowledge decreases thus a little but the difference is not significant. Globally we observe few effects even if the amount of knowledge (correct/incorrect) is better for grade 4 where on those 6 questions the difference is significant.

Coherence on the three pairs

We use the following coding in order to analyse the three pairs of questions together: if the student's answer is *coherent and scientific* three times, it is classified as *scientific*. If it is *coherent and scientific* twice, it is *mainly scientific*. If it is twice *coherent but false* it is *mainly false*. If it has at least two *incoherent* pairs of answers, it is *incoherent*. Then, all other combination of answers with one scientific, one *false* and one *incoherent* is grouped in a *mixed* category (see table 4 for the repartition in function of the grades and the test).

Table 4: Percentage of students for each category and each grade for the season concept (for the three pairs of questions Q4Q4t, Q1tQ5t, Q2tQ6t together)

	Grade 3		Grade 4		Grade 5	
	pretest	posttest	pre	post	pre	post
Incoherent	20.8	25	36.4	18.2	18.5	18.5
Mixed	8.3	4.2	27.3	18.2	7.4	7.4
Mainly false	4.2	20.8	9.1	4.5	7.4	3.7
Mainly scientific	54.2	29.2	27.3	45.5	44.4	40.7
Scientific	12.5	20.8	0	13.6	22.2	29.6

The *mixed* answers are mainly found in Grade 4 even after Escalate argumentative and research-like processes of inquiry. The percentage of them in Grades 3 and 5 are quite low mainly in Grade 3 after instruction. Incoherence was quite high in Grade 4 before instruction but decreased of 50% in the post-test. In Grade 3 only, we observe a small increase of *incoherent* answers in the post-test. In Grade 3, students had few *mainly false* answers (two *coherent but false* answers) but this amount is increased considerably after instruction while the *mainly scientific* answers (two *coherent* answers) decreases by about 46%. The *mainly false* category is very limited for the two other grades and decreases after Escalate program. On the contrary, the *mainly scientific* category reaches or remains at the level of about 40% for Grade 4 and 5 after Escalate program. For all grades the percentage of *scientific* answers increases from pre to post-test. In the pre-test, there are significantly more *scientific* models in Grade 5 than in Grade 4. If we look at each grade separately, we observe that in the post-test, Grade 3 students give less *mixed* answers than other answers and that the other categories are equivalent. For grades 4 and 5 the dominant category in the post-test is the *mainly scientific* one, and additionally, for Grade 5 the *scientific* category is also quite important. We thus observe a sort of developmental effect that goes from an equal repartition (except for *mixed* models) to a preference for *mainly scientific* and then to both *mainly scientific* and *scientific* answers. Moreover, we see that progressing through argumentative and research-like processes of inquiry (that is to say through Escalate program) seems to increase the amount of *mainly* and *scientific* answers for Grades 4 and 5 concerning season's concept while it seems to have the effect to "break" the *mainly scientific* initial answers of Grade 3 students. Indeed as we said, in the post-test, Grade 3 students' answers are equally distributed into all the categories except the *mixed* one. The main move is from *mainly scientific* to *mainly false*.

Conclusion

For the season concept, we observe globally a significant increase of scientific level of explanation or scientific knowledge about seasons after Escalate program mainly in grade 4 where this effect is significant for the scores. Nevertheless, concerning the coherence view, even if no significant differences appear, it is interesting to comment the results in a qualitative way. Indeed, as we showed in the previous paragraphs, the coherence between pairs of questions usually increases in the post-test while the *false* and *incoherent* models decrease except for grade 3 where the Escalate program did not produce positive effect on learning acquisition. It seems that it is in Grade 4 that the effect was the most interesting. Grade 3 children had difficulties in using the computer and might have missed the object of the debate in the Digalo as they have difficulties also to enter in a debate because, in the one hand, of their limited technical skills and because in the other hand of their difficulty of challenging the other's explanations. Very quickly there is a consensus between them in small group and in the whole class group. Grade 5 children were very interested in the subject both in astronomy, and in using computers. We observe that they are mainly in the *scientific* and *mainly scientific* categories. The amount of *incoherent* answers remains the same before and after Escalate program, so it did not have a relevant effect on coherence. It will be interesting to pursue this kind of analysis with the students in Grade 6 more particularly on this coherence aspect.

These global quantitative and qualitative analyses from the answers to a forced choice questionnaire give an idea on the repartition and level of understanding of the children globally grade per grade and its evolution from pre to post-test. A developmental effect is observed as expected and Grade 5 children have significantly better results than the other grades. Nevertheless, in order to analyse the evolution process, it is necessary to add other analyses like the analyses of the maps produced by the children and a more local qualitative analyse of the progression of some children in the groups' discussion. Indeed, we are both interested in the level of understanding or the kind of explanations of the seasons in link with the argumentative discourse through Escalate program and the effect of argumentation on the development of children' explanations. We thus need to focus on the discussion recorded and to describe the level of argumentation in order to link it to the knowledge acquisition process in science.

5.6.2. Elementary students 'argumentative dynamics through Escalate Program: Digalo-supported discussions and oral discussions

The analysis reported here focus mainly on the argumentation developed by elementary students first through Digalo map and then, how this specific artifact –a rebuilt map that incorporate previous claims proposed by the students but reintegrated in a new argumentative map- can then be an opportunity to generate new explanations (and perhaps scientific one) of the phenomenon under study.

Description and presentation of the argumentative maps created through Digalo-supported activity

In the Digalo session, two students were in front of a computer and discussed with two other students who belong to the same group from the beginning of the Escalate Program in each grade level.

At the end of the activity, 6 maps were produced in grade 3, 6 also in grade 4 and 7 maps were obtained in grade 5. We will present some selected examples of maps for the three grades in order to illustrate three different kind of typical maps (from a low level of argumentation to a high level) and the particularities of each grade.

Grade 3
In grade 3 what appears in the maps is that the students are able to use Digalo even if there are few propositions as the students spend more time to write on the computer. But from an argumentative point of view they are able to go deeper in the explanations in order to explain why they agree or disagree. The types of justifications which are used are mostly functional (see map 1) or based on the fact or sometimes came from authoritarian point of view (teacher, scientific document) or cultural one (TV). The dynamics of argumentation are more often claim or counter-claim and justification (see map 2). The opposition/discussion is sometimes on the justifications and not on the hypothesis itself.

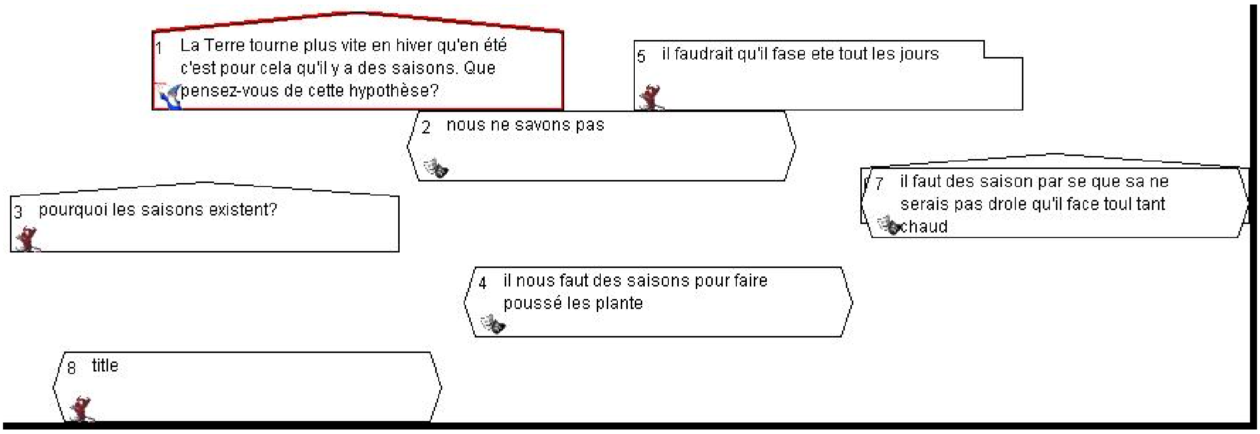


Figure 6: Map 1 obtained in grade 3 from the initial question: "**the Earth turns quicker in winter than in summer that is the reason why there are seasons. What do you think about this hypothesis**?"

In map 1, five propositions are given. The first answer is "we do not know" then a why-question is asked: "why are there seasons?" then a functional justification is brought "we need seasons to make the plants grow" and then "it should be summer every day" and "we need seasons because it would not be funny if it is always hot". So the last two propositions are not very grounded. Here what appears that is not present in Grades 4 and 5 is the fact that the explanation is functional: it is because it helps plant to grow that there are seasons.

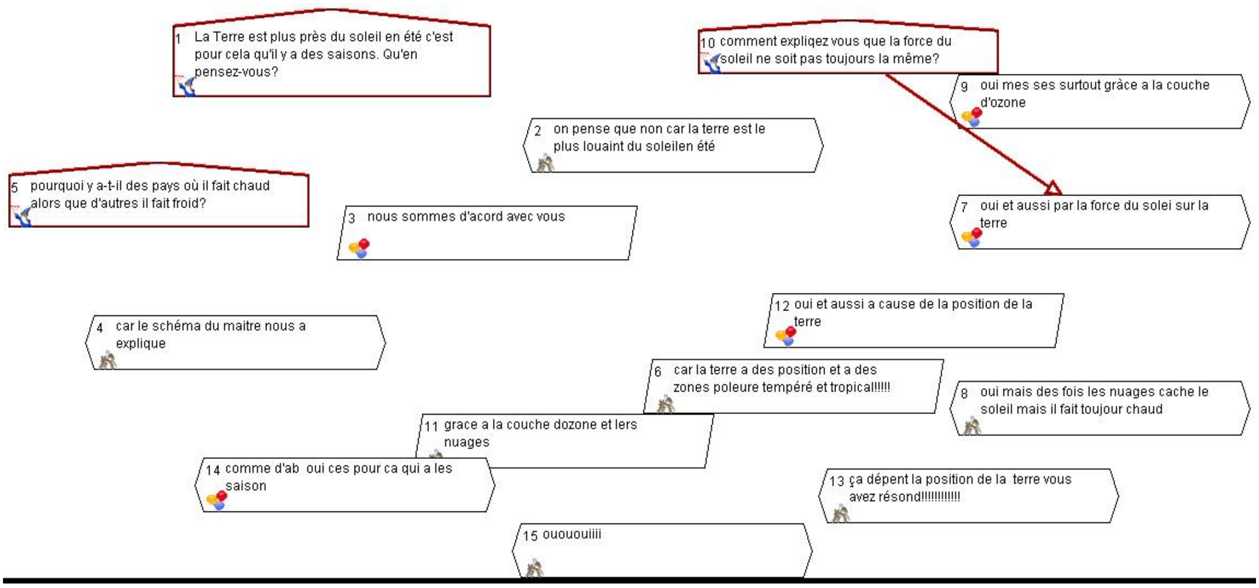


Figure 7: Map 2 obtained in grade 3 from the initial question: "**the Earth is near the Sun in summer: that is the reason why there are seasons. What do you think?"**

Twelve propositions composed this map 2. The first claim is "we think no because the Earth is far away from the sun in summer" then an agreement follows 'we agree with you". Then a justification is brought: "because the teacher's figure has explained us". Then a moderator has asked a question "why are there countries where it is hot and others where it is cold?" The answer is "because the Earth has some positions and has temperate and tropical parts". And another justification is brought "yes and also because of the position of strength of the sun on the Earth". Then "yes but sometimes there are clouds that hide the sun but it is always hot". This idea is pursuing in reference to the ozone layer. Then a moderator ask "how can you explain that the strength of the sun is not always the same?" the explanation is "because of the clouds and ozone layer" and the other partners add the "position of the Earth", then the other group approve the idea of the position of the Earth and it ends. Each time a claim is proposed; the students look for justifications and agree about them, they complete each other with different elements from their own observation (clouds) and from the teacher (figure and ozone layer).

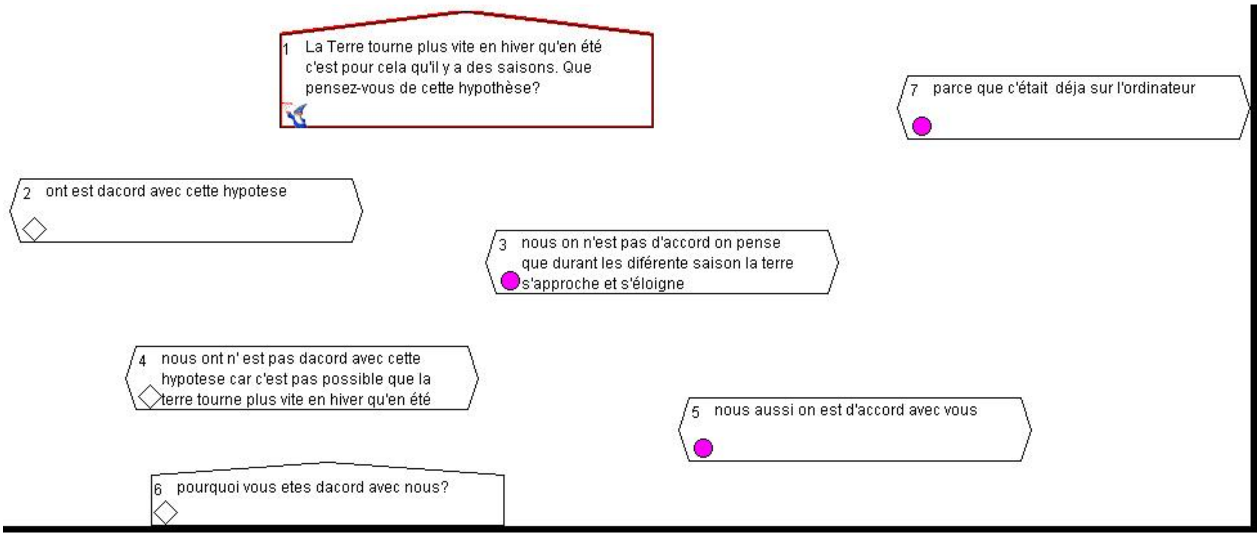


Figure 8: Map 3 obtained in grade 3 from the initial question: "**the Earth turns quicker in winter than in summer that is the reason why there are seasons. What do you think about this hypothesis**?"

In this map 3, six propositions are developed. The first two students immediately agree with this hypothesis whereas the other two disagree and develop a counter claim "we do not agree we think that during the different seasons the Earth is nearer or far away". The first group proposes a counter-claim to the first hypothesis (in contradiction with their first proposition) "we do not agree with this hypothesis because it is not possible that the Earth turns faster in winter than in summer". Then a consensus is reached. The others agree with that. But the last two propositions do not allow having more information about the students' understanding of the seasons. A why-question is asked from one group "why do you agree with us" and the answer is "because it was on the computer".

Grade 4

In grade 4, the maps are not very developed but most of the claims are justified by the students. The justifications are more often linked to observation in daily life (about the fact that the movement of the sun is not equivalent in winter and in summer). The dynamics are not very often claim counter-claim reply but rather a claim is proposed by the initial question or hypothesis which came from grade 4 students' previous work and it is or approved or dismissed (counter-claim) and then some justifications are brought. But there is a sort of juxtaposition of justifications rather than a dialogical way of debating and pursuing the discussion (see maps 1 and 2). Nevertheless, the level of argumentation found in the maps is higher than the one found in grade 3.

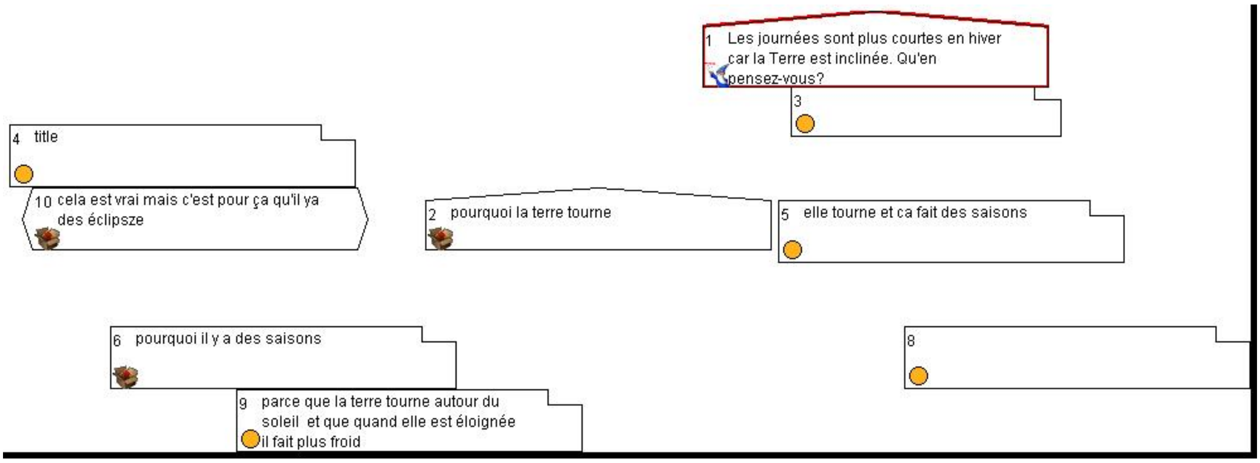


Figure 9: Map1 obtained in grade 4 from the initial question: “**the days are shorter in winter because of the tilt of the Earth. What do you think?**”

This first map is composed by five propositions, all are on the seasons. It begins with one why-question: “why does the Earth turn?”, the answer given by the other partners is “it turns and there are seasons” it is not really a deeper explanation. The first partners ask another why-question again “why are there seasons?” and the answer which is given explains “because the Earth turns around the sun and when it is far from the Sun it is colder”. The second partners explain the seasons because of the movement of the Earth around the Sun and because of the distance of the Earth from the Sun. The discussion ends with an approbation of that by the other partners and they add “it is true but it is because of that that there are eclipses”. One claim is really discussed during this map: the question of the origin of the seasons. The idea proposed as a start is not taken into account and the students focus on the movement of the Earth around the sun and the distance hypothesis to explain the seasons.

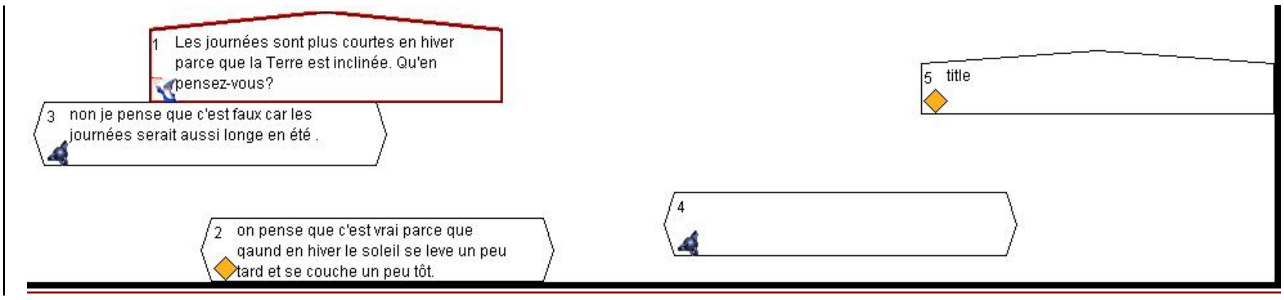


Figure 10: Map2 obtained in grade 4 from the initial question: “**the days are shorter in winter because of the tilt of the Earth. What do you think?**”

This second map is very short: it is composed only by two propositions in opposition: the first proposition is a counter-claim “no I think it is false (the fact that the days are shorter in winter because of the tilt of the Earth) because the days are as longer in winter as in summer”. The second group answers with a counter-claim addressed to the first Counter-claim by “we think it is true because in winter the sun rises later and sets earlier”. This last counter-claim (which is a claim in favour of the first initial question but in opposition with the first answer) develops an explanation based on the observation of the Sun’s movements. What is interesting here is that even if the map is very short all the propositions are justified.

Grade 5

Seven maps were realised by seven groups of four students. The question that initiates the discussion through Digalo came from the different hypotheses that emerged from the previous activity before the Digalo Session. The students have to explain first intuitively "why is it hotter in summer than in winter", and then through the used of data on specific scientific documents such as figures with real distances between Earth and Sun at the four seasons and temperatures in different countries prepared by the teacher. This work is realised first in small group of four students and then presented in the whole class group following by a debate in class.

Two maps began with the question: "**summer is due to the fact that the Earth moves nearer the Sun. What do you think?**" Two other maps began with "**Half of the Earth is lightened by the Sun and the other is not. Can it explain why it is hotter in summer than in winter?**". One other map was initiated by this question "**The heat in summer is due to the fact that the sun is higher. What do you think?**". Two other were initiated by "**the sunrays arrive straight on the Earth in summer that is why it is hotter than in winter. What do you think?".** These questions were first explanations/hypothesis given by the small groups of students to answer the initial question "why is it hotter in summer than in winter?" and transformed in question to initiate the debate on Digalo. As for grades 3 and 4, we will select some maps to illustrate the main use of the argumentative map by Grade 5 students (see maps 1, 2 and 3).

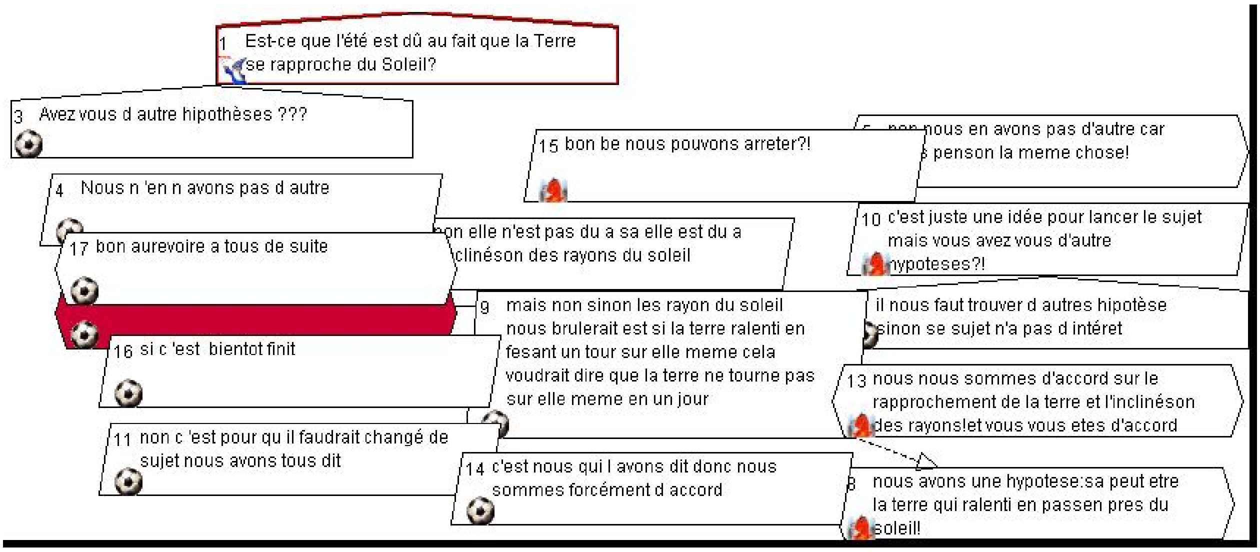


Figure 11: Map1 obtained in grade 5 from the initial question: "**summer is due to the fact that the Earth moves nearer the Sun. What do you think?"**

This map 1 in Grade 5 is composed by 14 propositions: three are questions and the others are claims or counter-claims and justifications. The first proposition is a question "do you have other hypothesis?" then the different participants answer they did not have other explanation so there is very quickly a sort of consensus "we do not have another explanation because we think all the same": so the hypothesis of the variation of distance of the Earth to the Sun is the one which is first dominant. Then, another hypothesis (claim 2) is proposed: "it is not because of that it is due to the tilt of the sunrays" then another hypothesis (claim 3) is juxtaposed "we have another hypothesis: it could be the earth which slows down when it passes near the Sun". This new claim generates a counter-claim (CA3 and CA2) "but no otherwise the sunrays burn us and if the Earth slows down in doing a turn on itself it would mean that the Earth does not turn on itself in one day". The debate conclusion ends with a consensus on two claims which are approved: the tilt of the sunrays and the rapprochement of the Earth.

Three mains claims were proposed first there are juxtaposed and then two of them were counterclaimed by the same participants with a justification involving other knowledge on astronomy (the length of translation of the Earth in order to reject the "slowing down" of the Earth). The dynamics of the argumentation are the following: C1-C2-C3-CounterC2&CounterC3-Reply (acceptation of C1and C2). Three main arguments are proposed.

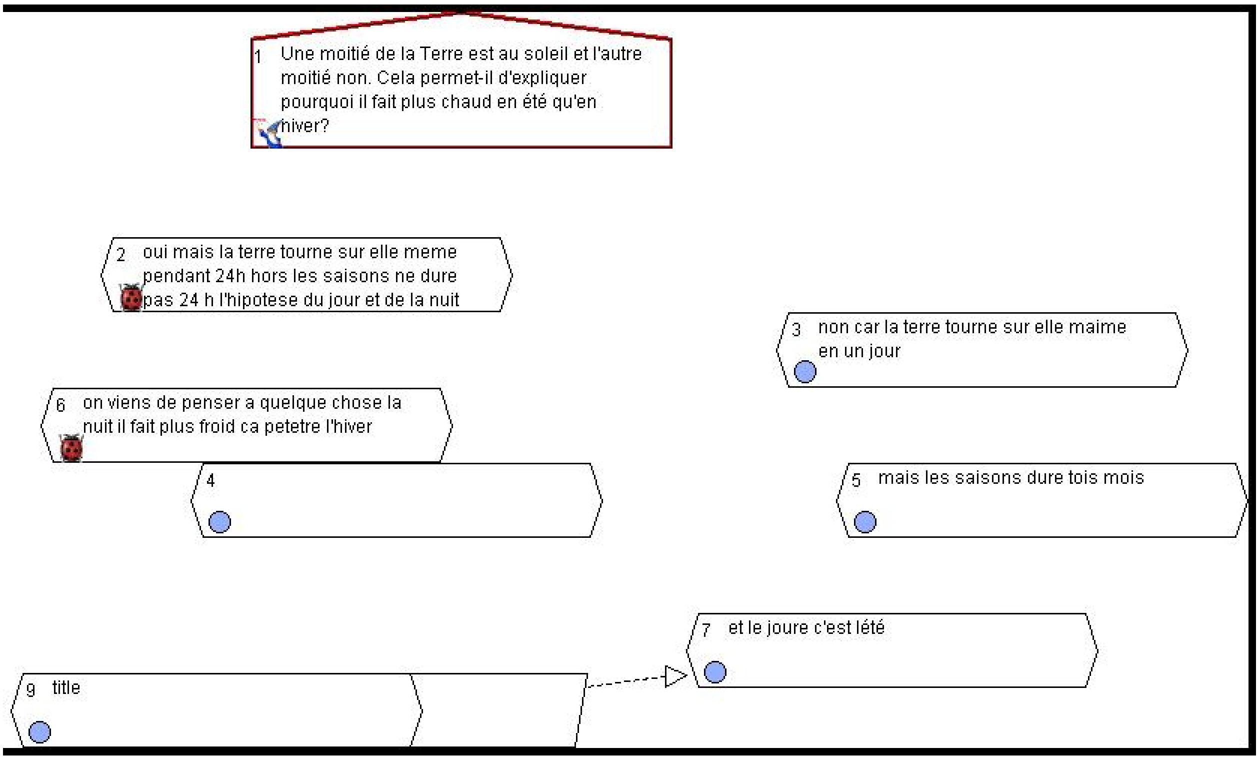


Figure 12: Map2 obtained in grade 5 from the initial question: "**Half of the Earth is lightened by the Sun and the other is not. Can it explain why it is hotter in summer than in winter?"**

The second map of Grade 5 is composed by five propositions: the first intervention is a counter-claim (CA1) which approves that fact that "the Earth turns on itself in 24 hours but the seasons do not last for 24h, it is the hypothesis of night and day". A counter – claim on this CA1 is "no cause the Earth turns on itself in one day but the season lasts for 3 months". The other participants propose another claim "we think to another idea: during the night it is colder so it can be winter" and the other participants follow this second claim adding "and the day can be the summer". Here there is confusion between day and night and the seasons even if it is well defined at the beginning.

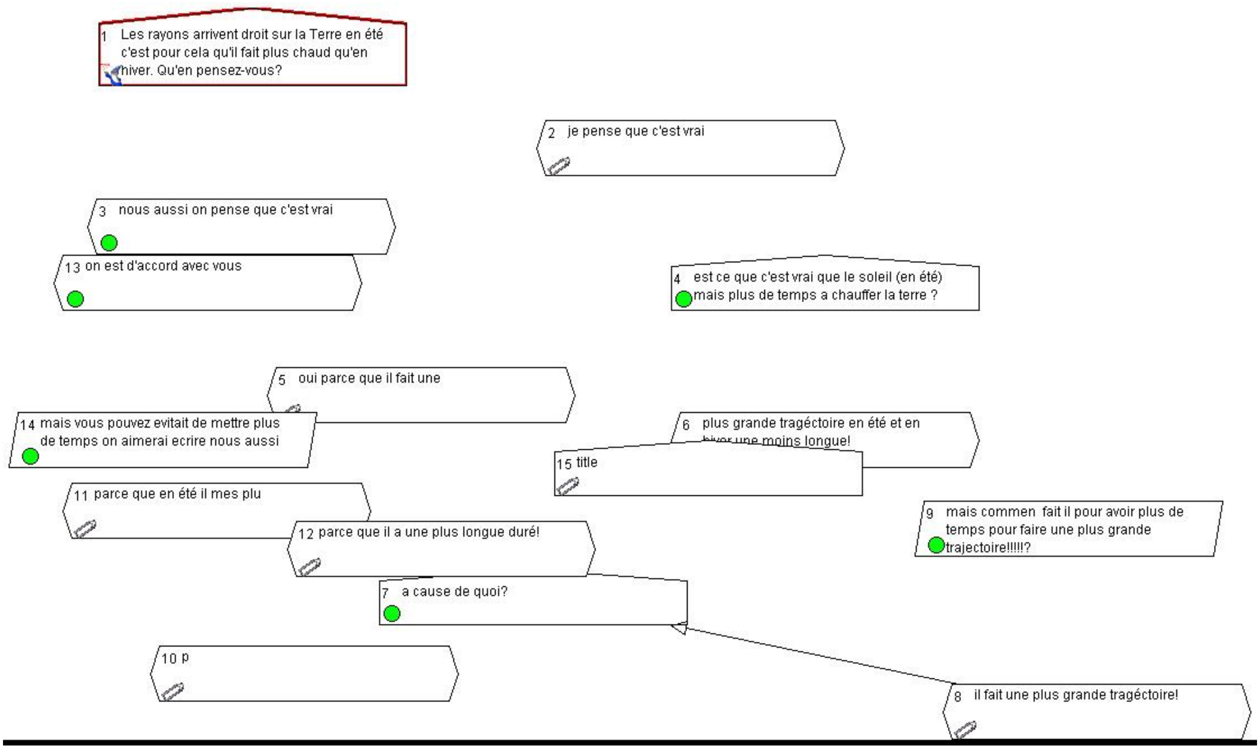


Figure 13: Map3 obtained in grade 5 from the initial question: "**the sunrays arrive straight on the Earth in summer that is why it is hotter than in winter. What do you think?"**

This third map of grade 5 is composed by 9 propositions: three are questions seeking for further explanations always asked by the same partners. The two first propositions agree with the initial proposition about the fact that the sunrays arrive straight on the Earth. A question is proposed " is it true that the sun in summer takes more time to heat the Earth?" the answer is given by the two other participants: " yes because it has a bigger trajectory in summer and less big in winter", the collaborators follows by a why question in order to have a deeper explanation "and why?" the answer given re-used the same justification "it has a bigger trajectory!" and the question is then developed to reach a better understanding: " but how does it work to have more time to have a bigger trajectory?" the answer proposed that "in summer, it has a longer length." The debated ends with a consensus "we agree with you". Then a reproach about the time taken to write is enounced by the partners.

Comparison of the level of argumentation observed in the maps for the three grades

We observe from table 5, that in Grade 5, the maps are more complex (this pattern Claim-CounterClaim-Reply is only present in Grade 5) and they are richer (in terms of number of proposition, argumentative dynamics and questions) than in the two previous grades. The claims are more often challenged and the justifications are shared in the sense that they came from a question (more often a why-question) asked by the partner. What is really characteristic of Grade 5 is the fact that they try to find hypothesis to challenge others' point of view. The debate looks also more structured: the initial question is really questioned and not systematically defended and justified; some of the map ends with a consensus or not but there is a sort of conclusion of the debate "we agree with each other" or when there is a "we do not agree", students try to pursue the reasons why they disagree through Digalo. Indeed, on the contrary, the main practise of the argumentative map observed in grade 3 was a debate where only one or two ideas were developed but not discussed by the other children. Sometimes the maps revealed a debate where a low level of argumentation or justification was reached. In grade 4, the same kind of maps was found but also some maps with deeper argumentative processes. Nevertheless, it appeared that in Grade 5, whatever their kind; the maps were always richer qualitatively than in the two other grades.

Table 5: synthesis of the different dynamics of argumentation by mean frequency of different kinds of propositions in all the maps realised in each grade

	Claim only (mean number of different claims per map)	Claim or counter-claim +justifications (mean number per map)	Claim and Counterclaim (mean number of this pattern per map)	Claim-counterclaim Reply (mean number of this pattern per map)	Questions (mean number of questions per map)	Mean number of propositions per map (within the subject)
Grade 3 (6 maps, N= 24)	4/6= 0.66	5/6=0.83	3/6= 0.5	0	6/6= 1	43/6= 7.16
Grade 4 (6 maps, N=24)	4/6=0.66	5/6=0.83	1/6=0.05	0	3/6= 0.5	18/6= 3
Grade 5 (7 maps, N=28)	9/7= 1.28	8/7=1.09	2/7= 0.28	2/7= 0.28	5/7= 0.71	50/7= 7.4

What is interesting when we analyse the maps is to shed light on the fact that even if all the proposition which are claims produced by students in Grade 3 and Grade 4 are justified “we think xxx because yyyy”, the Grade 5 students also justified their claims but more often the justifications are due to questions from the other partners more often introduced by why-questions. It is more dialogical way of thinking together in the sense where the reasoning seem to be shared between the partners of the debate rather than coming from one group of partner.

We develop now few examples through case studies in order to illustrate the migration of ideas and explanations through Escalate Program.

Few examples through Case studies

Two groups of four students have been studied in Grade 5 at each step of the Escalate Program (at each different session).

The first group is composed by Brice, Audrey, Ludivine and François: at the pre-questionnaire, only Brice has a scientific knowledge about the seasons: he knows that the distance is not a good hypothesis to explain the season, he knows that the Earth rotates around the sun in one year and about the fact that in north and south hemisphere there is not the same season at the same time whereas two countries in the same hemisphere have the same season.

In the pre-test, Audrey and Ludivine know well about the revolution of the Earth and about the link between hemispheres and seasons but they both believe in the distance hypothesis to explain seasons (the Earth is near the sun in summer). They globally give explanations which are mainly scientific. François gives incoherent answers at the question about distance (the Earth is and is not going away from the sun) and he does not know how the revolution of the Earth lasts around the sun. He has a mixed level of understanding about seasons.

The second group is composed by Lucien who, in the pre-test, has the same profile as Brice (scientific level of understanding of the seasons), Amandine who has a mainly scientific level of knowledge as Ludivine and Audrey; Gabrielle who has the same level of understanding as François and Gwendoline who has an incoherent level of understanding of seasons (she gives two incompatible answers for the revolution, the hemispheric and the distance questions).

Table 6: Levels of understanding and explanation at the beginning and the end of the Escalate program for 8 Grade 5 students

Students & group	Level of understanding measured from questionnaire (pre-test)	Explanation	Level of understanding measured from questionnaire (post-test)	Explanation
Brice (group 1)	Scientific & coherent		Scientific and coherent	
Audrey (group 1)	Mainly scientific (coherent)	+ Distance	incoherent	
Ludivine (group 1)	Mainly scientific	+ Distance	Mainly scientific	
François (group 1)	Mixed		Mainly scientific	
Lucien (group 2)	Scientific & coherent		Scientific and coherent	
Gabrielle (group 2)	Mixed		Scientific and coherent	
Gwendoline (group 2)	Incoherent		Mixed	Distance
Amandine (group 2)	Mainly scientific	+ Distance	Mixed	Distance

We observe from table 6, that Brice and Lucien kept their high level of understanding about seasons from the pre and post test. Audrey had a regression because she moved from mainly scientific (correct answers for revolution and hemispheric pairs of questions) with the distance hypothesis to totally incoherent answers: she gave in the post-test for each pair of questions, two incompatible answers.

Ludivine remained mainly scientific but her ideas moved: she lost the distance hypothesis and thus answered correctly the distance questions in the post-test but she became incoherent regarding the revolution pair of questions.

Francois increased his level of understanding about revolution but remained incoherent regarding the distance pair: the Earth is and is not going away from the sun.

Gabrielle moved to coherent and scientific while she was in a mixed category in the pre-test and had incoherent answers for the distance pair.

Gwendoline had three incoherent pairs of answers initially, in the post-test, she became mixed (one correct pair, one false pair and one incoherent pair) with the distance hypothesis. She improved in coherence but not in correctness because she believes no in the distance hypothesis. Amandine decreased for the revolution questions where in the post-test she answered incoherently.

We are going to follow what kinds of hypothesis and arguments each group defends during the different escalate activities.

After the pre-test, the students had a brief debate in the whole class to explain why it is hotter in summer, then they work by group on several scientific documents (figure with real distance Earth-sun at the four seasons, and a calendar with different temperatures and countries).

Extracts of discussion of group 1
The group 1 discusses on the initial question: why is it hotter in summer than in winter. They look for different hypothesis and use documents the teacher has distributed.
Ludivine 1: “I don’t know, the Earth rotates on itself.. and revolves around the sun.”
Brice 2: “Yes, when you have the Earth<he represents the Earth by joining his two hands > when we are in front of the sun rays for example in winter, if we are more tilted, the rays turns more strangely, thus it is not hot.<he develops diagonal gestures to represent the sun rays arriving on the Earth>” (**scientific explanation of the seasons**)
François 3 : “The sun is closer to the earth” (**distance explanation**)
Brice 4: “So it would be concerning the sun, the earth that rotates…”<it had a gesture of rotation with his hands > …(inaudible) the sun rays tilted…
Ludivine 5: “the sun does not move”
Brice 6: “no the sun does not but it is the earth with revolves around the sun…”<he has a gesture with his two hands to represent the earth> it depends …(inaudible) regarding the Earth
The teacher arrives 7: “you exchange, you search and share your hypotheses, you have several ones”
Brice 8: “We must find another hypothesis because we are not sure it is the correct one”
François 9: “It is the sun rays that light, Brice said it was the sun rays that bright..”<he indicates the external light by the window>
Brice 10:” It depends on the tilt of the rays, if they fall straight on us or tilted otherwise. Or there is another (hypothesis) it is the Earth rotation around the sun, it is a hypothesis also…”

Brice 11 draws on a paper his hypothesis and explains to the group: “tilt of the Earth and rotation of the Earth around the sun”
Brice 12 proposes a synthesis of what he has noticed: “I have written that the sun rays due to the rotation of the Earth around the sun ….
François 13 : “it is the tilt of the sun”
Brice 14: I don’t know you write what you want and then you interpret it as you prefer I give you an idea if you do not want to write it …
(…)
The teacher comes back 15: “what are your hypotheses?”
Brice 16: euh it is due to the rotation of the Earth around the sun and to the direction of the sun rays < Brice does again the diagonal gestures to represent the sun rays arriving on the earth>
Teacher 17 : Ok and to François “why are you laughing? Is it clear what Brice said?”
François 18(inaudible)
Teacher 19 : do you understand what Brice has said? Do you have other hypothesis?
François 20: it is the Earth which is near the Sun
(…)
Teacher 21: “you have two hypotheses which are not the same so you have to agree you have to see if your hypotheses hold out why and why not…”
Then the students follow their own ideas: Brice explain again the tilt of the Earth and the sun rays which do not arrive similarly depending on the rotation and François who is defending the distance explanation. They do not choose which one they are going to develop in front of the class group.

Group 2 :
Gwendoline 1: who is beginning?
Gabrielle 2: I have drawn a figure, I have drawn the Earth < she represents the Earths on her book without a real drawing but with a circular gesture> and there is France here.
All the students: laughing
Gabrielle 3: and there I have done the sun <she represents the sun on her book without drawing it> and there winter it is tilted <she had a tilted gesture>
Gwendoline 4: you know do you remember?
Gabrielle 5: yes
Gwendoline 6: at a certain moment he (teacher) asked to circle I don’t’ remember what…
Gabrielle is searching in her notebook
Gwendoline 7: There are two earths tilted
Amandine 8: there have two earths <she represents them on then table> and an Earth where there are arrows
Gwendoline 9: because I do not have this lesson so I work on the earth tilted <she represents the tilt of the Earth with her hands>
Gabrielle 10: and you Lucien do you have an idea?
Lucien 11: the Earth is near the Sun
The other girls 12: ah yes Ok
(…)
Gabrielle15: and there look the sun rays are tilted > she makes a gesture of the tilt> and then in winter they arrive like that < she makes an horizontal gesture to show they arrive straight and not tilted>look on the book (and she shows a document).(**Nearly scientific**)
Teacher 16: I didn’t ask you to search on your lesson, do you have any ideas?
<the students closed their notebook>
Amandine17: I have noticed that the sun is near the Earth in fact. (**Distance hypothesis**)

Teacher 18: Ok what do you think ?
Gabrielle: I said that the sun rays are straighter and in winter they are tilted… (**Nearly scientific**)
Teacher 19(to the other two students): and do you have the same hypothesis?
(they seem not to know)
Teacher 20: Lucien do you have one?
Lucien 21:euh yes when the Earth is near the Sun (**distance hypothesis**)
Teacher 22: does it look like the other hypothesis?
Amandine23: mine!
Teacher24: ok
Teacher 25: so now you try to reflect on this hypothesis <he shows Lucien> and eventually you try to reflect how you can verify it? Is it true or not? Then you take Gabi'hypothesis if it is not the same and you discuss it and you try to agree on one hypothesis.
Gwendoline 26: I would like to know if it is the eart which is near…near the Earth…
Gwendoline 27: I think that the Earth is not moving I do not think…
Amandine28: bah yes it's moving (…)
There is long discussion between Amandine, Gabrielle and Gwendoline about the fact that earth is rotating around the sun and turns on itself but they have a problem about the idea of coming near the sun and the conclusion given by amandine is if it is not the Earth which is going near the Sun perhaps it 's the sun which is going near the earth..
Lucien explain the group his figure: "the sun is not moving that's it">shows his drawing and add a circular gesture to his drawing>…
they agree on the fact that the Earth is near the sun, Lucien will be designated to be the group's reporter. In fact it will be Gwendoline who will be the reporter for the group 2.

When they report what is their hypothesis to the whole class:
Brice explains that the Earth is near the sun and then it is hotter
Then several students give their hypotheses and Gwendoline proposes a figure on the blackboard: when it is hotter when it is colder in winter …night and day
The teacher adds: we have learnt that the Earth turns on itself in...?
Students: one day...
Gwendoline develops the hypothesis of the distance with a figure
Later Brice explains the hypothesis he has developed alone in his group: the one about the tilt of the sun rays…

Then on Digalo Map:
Group 1 develops the map 1 Brice and François who did not have the same hypothesis are together in front of the computer discussing with Ludivine and Audrey who are on another computer at the opposite side of the room.
Brice and François first develop the scientific explanation about the tilt of the sun rays, then the two girls propose another hypothesis the fact that the Earth goes lower when it is near the sun but this proposition is counter-claimed by the two boys who develop an argument against this idea (see proposition 9 on map 2). The girls conclude that they agree on the distance and the tilt of the sun rays and the boy agrees too=> two main hypotheses co-exist: distance and tilt of the sun rays

Group 2: Gabrielle and Gwendoline are together on a computer "in front of" Amandine and Lucien (who develop both the distance explanation in previous interactions). They immediately agree on the fact that the rays arrive straight on the Earth in summer. They develop an explanation about the fact that in summer the trajectory of the sun is bigger than in winter (mainly Lucien and Amandine answering the two girls' question). There is no additional hypothesis or justification in the debate on Digalo.

Group 1 when they work on the rebuilt map 2 in group
Brice 1 who reads the map: "They say that *the Earth is closer to the sun it is true because the sun makes a longer path in summer*"
François2: "Than in winter"
François3: "It makes a longer path in winter. It is not the sun that makes a path. The sun does not move"
[...]
Brice: "then after, the *sun when it is high it is colder and it is winter*."
François : "It is wrong"
Brice : "it is wrong because relatively to us if the sun is here, we rotate always in the same direction"<Brice realises a rotation movement with his hands>
François: "you know why it is written? When there is the Earth the sun when it is high it is cold it is winter"
Brice: "the sun when it is high it is hot" it is higher so the sun rays arrive straight <he shows that the sun rays arrive vertically> and at the bottom in winter the sun rays arrive like that <he represents a diagonal>
Ludivine: "yes"
Brice: "ah yes because the rays arrive straight"
[...]
Ludivine: "but in the table it was shown that the distance in winter and in summer and the earth was closer"
Brice: "no it was the same"
François :"not in summer, in winter"
Ludivine: "no it was 50 M km in summer and 45 Mkm, I don't know in winter"
Brice :" no it was about the same"
Brice" it was closer in winter I remember"
Ludivine: "It is what I said"
[...]
Brice : "*The tilt of the sun rays*, yes we said that, the sun is higher, thus it is due to the tilt of the sun rays relatively to the Earth, then the hypothesis, *the Earth goes slower when it is close to the sun*, it is true, no *it is wrong otherwise the rays would burn us and if the Earth was slower during one rotation on itself, it would be in contradiction with what we say, the Earth wouldn't make a rotation in 24h* (it is what is written on the map) but in less, so it is wrong"

The students of group 1 agree at the end with the hypothesis of the tilt and Brice explains why the distance hypothesis is not acceptable (as the distance in winter is less important than in summer so if we rely only with the distance it will be the contrary hotter in winter).

In the last discussion the use of the rebuilt maps helped the student of this group to go further in their explanation by trying to find evidence for their arguments and to try to find evidence to reject other arguments. We observe an increase in the level of argumentation by the fact that all the arguments are justified with the help of previous knowledge from the scientific documents.

Group 2 interacting around the rebuilt map 2: they revise one by one the claim and proposition in the map and approve or dismiss them by using drawings and explanations but they spend their time only on one problem: the fact that we have the impression that the sun is moving but it is not and we have the impression that the Earth is not moving but it is…

This phase was followed again by a collective debate in class focusing on the seasons where the tilt hypothesis emerged from the children themselves. The teacher was really happy from that.

Conclusion about these two cases
What is interesting in these two groups is that there are two boys who have a scientific conception of the seasons at the beginning: one, Brice is using it to explain the idea of tilt of the Earth whereas the second, Lucien, never mentions it, he develops rather at the beginning the distance hypothesis. But Brice often tries to develop, explain interact with the other whereas Lucien says nothing except when the teacher or one of his partner asks him to develop an idea deliberately.

In group 1, the interactions are mainly between the two boys and Ludivine interacts only in the last group session on the rebuilt map to develop her point of view whereas Audrey never gives her point of view. This passive way of interacting in all the session does not allow her to develop any kind of scientific conception of the phenomenon. On the contrary, she became completely incoherent in the post-test by giving opposite answers to the three pairs of question. The other students who try to act and give explanations, try to search for verification… enter at this end in a sort of routine of argumentation where it becomes a habits to demonstrate or dismiss what has been said by others. All of these three students increase their level of knowledge at the post-test and during the interacting phase mainly the oral ones. Brice occupies the role of mediator and moderator : he explains, asks questions in order to involve other points of view to emerge and at the end of an interactive session he always summarize the different viewpoints.

In group 2, no student occupies the role of mediator and moderator. Gabrielle and Gwendoline who interact a lot to give their viewpoint and try to understand each other change their way of thinking about the seasons' phenomenon in a more scientific way even if Gwendoline has a mixed level of understanding. Gwendoline has been using drawings a lot to try to develop both distance explanation as well as the idea of tilt of the sun rays but she often fails explaining on her own the second one. It seems that this scientific explanation is not yet appropriated by this student who tries to make it co-exist with the distance explanation. Lucien keeps his scientific level of understanding and Amandine who was not interacting a lot at the end has only developed a mixed level of understanding. Because no student occupies the mediator role, this group 2 sometimes spends too much time on one detail and does not have time to enter in a real debate about all the claims and propositions.

5.7 Dissemination

We performed dissemination at various levels:

- For teachers training, the initial project to develop since 2006 training in IUFM was not possible because it was too early but can be proposed in the future. . Nevertheless, the Escalate project has been exposed to trainers and will be integrated both in pre-service training (in the context of students' pedagogical dissertation about an implementation of their choice in school) and in in-service thanks to the concrete examples our implementation gave us.

- For in-service teachers, we developed workshops with four different teachers in two different schools concerning ours cases in astronomy
- We have established contacts with two other European Projects: PENCIL particularly with the Cité de l'Espace involved in it and POLLEN (meeting Pierre Lena in a conference in Toulouse and e-mail contacts)
- We have distributed Escalate brochures in meetings (Cospar in space education session)
- One communication in a symposium in Earli meeting (August 2007), entitled the "development of scientific knowledge through the use of argumentative maps and inquiry-based activity in elementary school" has been accepted.

5.8 Lessons learned

As a conclusion, we develop here two kinds of lesson learned from the teacher's point of view, from the students' one as well as from the researcher's point of view in order to shed light the way the system worked during Escalate implementation and evaluation.

- *From the point of view of the teacher*:
    - One main important issue in this program is to find a way to make the students progress, change their view of the situation under study. So the main important question the teachers ask is: How to get the pupils disturb regarding their initial explanations: they insist on the role of the construction of the situation and the necessity of creating a conflicting situation in order to develop the research like processes of inquiry emerged.
    - The difficulties they encountered are about the fact that even when students develop a false explanation they did not correct it and try to make the students find by themselves why it is acceptable or not from a scientific point of view. This particular point is difficult to face for some teachers depending on the type of didactical contract they have developed with the students. Sometimes the fact that the teacher does not correct the students is considered as a correct answer from the pupils' side.
    - The other important question is how to construct a progress in the activity itself. Within the different steps and activities proposed there is a progression through the Escalate program but it needs more time to develop this kind of inquiry and argumentative based approach not only on astronomy but on science in general.
    - The other point which is very important to outline is about the engagement of the teachers in the project: they work as voluntary and are unpaid …

So what seems very useful in order to understand better how the students can grasp new tools to think scientifically is to study in details the teachers' toolkits in order to analyse for example the teachers' documents, ways of interacting with the students… for example in Grade 5, the teacher was used with his class to practice "decentring" debate in literature or history so it would be very interesting to study this practice and how he uses it in science.

From the point of view of the students:
They appreciate working on the computer as they do not use it very often. The plurality of the activities (oral debate, Digalo debate, oral map-supported debate, drawings…) proposed was also very appreciated and help the students to support their thinking.
What seems to appear during all the activities through Escalate program is the fact that some of the students begin to change their way of understanding the object under study as the way they enter in these activity changes too. That is to say that as some of the students begins to develop their viewpoint, try to explain it to others and try to develop justifications; they begin to enter in a sort of questioning of their own knowledge and begin to reflect on their legitimacy. Entering in this reflection they begin to enter in a deeper understanding of the seasons. What seems very relevant in the Escalate program is to create a new map – a sort of reconfiguration of the students' previous claims and justifications what we called rebuilt map. It seems that this particular activity at the end of the argumentative and research-like phased activities helps the students enter in the reflection on their own thinking and on the others' one. This particular analysis of a written product helped them to develop a critical understanding of a scientific topic.

Andriessen, Baker & Suthers (2003) in their introduction Argumentation and confronting cognitions of the first of CSCL series noticed three kinds of learning from argumentation that we can develop here and specify with using a complex educational program combining argumentation and research-like processes of inquiry: **learning from the debate**, **learning about the debate** and **learning to debate**.

What we shed light with the evaluation part is different kinds of learning through Escalate Program: we can summarize what can be learned through this program (argumentative and inquiry based) : the results show that elementary students and particularly in Grade 5 can learn about a scientific topic through this educational device, in astronomy. **They learn from the debate and the research-like processes of inquiry**. A deepening understanding about the seasons and concepts associated with it such as revolution and rotation of the Earth, tilt of the Earth, hemispheres… For example in debating and searching hypotheses in collaborative activity the students gain a deeper understanding of the concept of revolution and can be more criticized against the distance explanation to explain seasons. We have seen that students in Grade 5 profitably participate in these argumentative and inquiry based activities as they develop more scientific understanding of the season concept. Argumentation is a part of the research –like processes of inquiry rather than another activity.

The students **learn about the scientific process** that is to say they learn to develop hypothesis try to develop proofs from scientific documents under study they learn to rely on scientific resources rather than on their own intuitions and in learning to think as scientists they learn to communicate about their thinking and to confront their arguments with others. Learning about the scientific process means learn to develop argumentation (production of arguments and counter-arguments in an interactive context) as well as learning to enter in a phenomenon from a scientific posture. We have shown that being able to reflect on an argumentative map may help the students enter in a reflexive stance which leads us to be able to reflect not only on others' arguments as well as on their own process of reasoning. This kind of learning about the scientific process implies **learning to debate in a scientific way**.

From the researcher's point of view:
We learn as researchers in psychology interested in learning and conceptual development that entering in educational system to propose new tools and new ways of practicing science in elementary school is a complex task. What did we learn from Escalate program? Concerning the initial context of implementation, we present the difficulties we encountered when we tried to propose in an academic way some Digalo based activities for in-service and pre-service teachers training and how we had to find alternatively the teachers we worked with. It appeared that no hour could be delivered to other activities than academic knowledge during the two years of pre-service training. It seemed possible to propose Digalo based activities in the context of "pedagogical projects" (pre-service teachers have to present a project about a subject of their choice, have to implement this project in a class and then write a document (dissertation) about that experiment). We show how, despite the real interest from the science trainers, some institutional guidelines from school inspectors, made the students choose other subjects. Regarding the in-service training, even if there were several theoretical possibilities to implement our project, we show that it was too early to be possible because, to be accepted in the training institute, the activities must already have been implemented and have final results to present concretely to in-service teachers. Because of all those difficulties to enter through the academic way, we present how we had to find other means to contact in-service teachers. We explain to what extent, the teachers we worked with, were pioneers and had all a personal interest to the subject. One of them was working in a space museum and the others had already participated to another science project and were very interested in being involved in a new innovative program. We show, despite the impossibility to use the official system, how we managed to conduct our implementations with success thanks to the huge implication of these teachers. The duration of the project has offered us some concrete examples of the use of Digalo and argumentation in science for elementary school children. So now observations and evaluation in class are available. Our experience with Digalo can be only now proposed to the academic and institutional programs because it has demonstrated its interest to be used in class.

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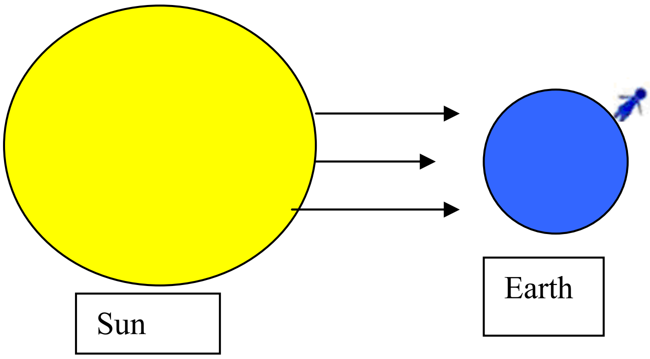
APPENDIX 1: Questionnaire

Choose the right answers

1. **Why are there nights and days ?**

   - ☐ Because if there were no night, we could not sleep.
   - ☐ Because the Earth revolves around the Sun.
   - ☐ Because day is here for us to stand up and night to sleep
   - ☐ Because the Sun revolved around the Earth.
   - ☐ Because the Earth rotates

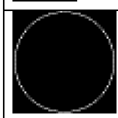
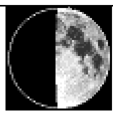
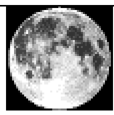
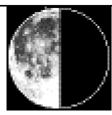
2. **Is it day or night for this person on Earth ?**



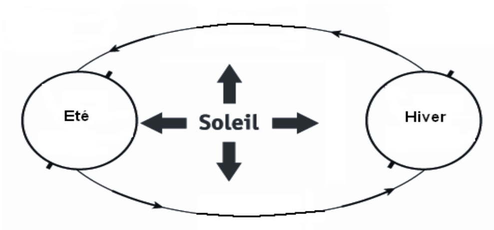
☐ d
a
y

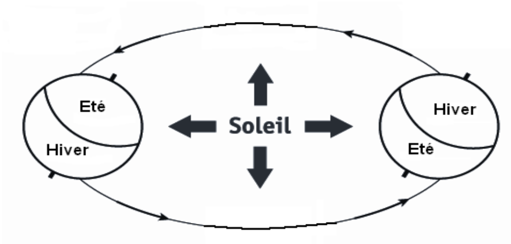
☐ n

3. **Complete this table with the appropriate names of the mon phases**

___________	First quarter	___________	___________
			

4. **Indicate the correct drawing for the Earth's orbit**





5. **My parents went with me at the bus station, I am going on holidays. I climb in the bus while my parents wait on the road for the departure of the bus. When the bus moves forward :**
   - ☐ I see my parents move forwards
   - ☐ I see my parents move back

6. **Choose the scientist who says the truth :**

The Sun revolves around the Earth in 24 hours

The Earth rotates on 24 hours

7. Gauthier is 8 years old. How many times did the Earth revolve around the Sun since he was born?

- ☐ **1 time**
- ☐ **8 times**
- ☐ **10 000 times**

8. A season lasts about :

- ☐ **1 month**
- ☐ **3 months**
- ☐ **6 months**
- ☐ **1 année**

9. **For each line put a cross in the convenient case.**

	True	False
1. The Earth revolves around the Sun in 24 hours		
2. When it is summer in Toulouse (France), it is winter in Spai		
3. In winter days are longer than nights because the Earth r faster during the day than during the night.		
4. In summer the Earth is closer to the Sun		
5. The Earth revolves around the Sun in one year.		
6. When it is winter in France, it is summer in Australia.		
7. There are phases of the moon because the clouds mask a par Of the moon.		

ESCALATE: The White Book

Chapter 6: Description of the experimentations in England

S. Simon and S. Johnson

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6.1 Introduction

School science teaching in the UK has traditionally been focused on the content of science – that established body of scientific knowledge that forms the bedrock of the curriculum and school science examinations. Yet recent debates about science education emphasise the importance of the nature of science and the processes of critical reasoning and argument (Driver, Leach, Millar, & Scott, 1996; Driver, Newton, & Osborne, 2000; Millar & Osborne, 1998). There is a growing need to educate our students about why we believe in the scientific world-view – that is to see science as a distinctive and valuable way of knowing. Such a shift in emphasis requires that the teaching of science should focus more on the evidence and arguments for scientific ideas, and help students develop the skills needed for engaging in fruitful argumentation.

Research shows, however, that only if argumentation is specifically and explicitly addressed in the curriculum will students have the opportunity to explore its use in science (Khun, 1991; Hogan & Maglienti, 2001; Osborne, Erduran, & Simon, 2004a; Zohar & Nemet, 2002). The teaching of argumentation through the use of appropriate activities and teaching strategies can provide a means of promoting social skills, reasoning skills and knowledge building. The evaluation reported here focuses on the implementation of an ICT development, digalo, that has been designed to enhance students' argumentation and assist teachers in their mediation of students' learning.

This chapter outlines the context in which the implementation of cases using digalo took place in the UK and presents an evaluation of the implementation. A series of training workshops was planned at the Institute of Education that would focus on teaching argumentation and the use of digalo. The workshops were advertised in our London networks – including teacher training partnerships, Masters programmes, Science Learning Centre London contacts and other research projects. The approach to teaching argument that guided the design of the workshops drew on previous research on teaching argumentation (Osborne et al 2004b, Simon et al 2006). Once teachers were fully involved in the training workshops, cases were co-constructed by researchers and teachers. Teachers taking part came from primary and secondary schools, all following different curricula, and each case was designed according to individual needs. Four teachers eventually took part in our evaluation of case implementation. The chapter reports on these cases and the contexts in which the evaluation took place. The cases implemented in London drew on previous research and development on argumentation in science, using the digalo tool to enhance argumentation practices. The visualisation provided by digalo created the means for enriching discussion and argumentation of scientific and socio-scientific issues with students across a wide age-range.

Our focus in the Escalate project was on evaluating case implementations at three levels. At a macro level we looked at how argumentation activities using digalo could be incorporated into the science curriculum, and how the context within each school facilitated or constrained implementation. For example, curriculum constraints were particularly apparent in secondary schools, limitations of computer facilities meant that digalo could only be used at certain times, and technical problems dictated that digalo could only be used in asynchronous rather than synchronous modes. At a meso level, we focused on evaluating teachers' developing pedagogy of argumentation and the role that digalo played in this change, we also looked at students' response to using digalo – their engagement and interest. At a more micro-evaluative level we analysed in detail some of the outcomes of digalo activities, in terms of conceptual change (Case A), quality of argumentation visualized through digalo maps (Cases A-C) and at student outcomes measured in end of year assessments (Case D).

Conclusions and implications for future research and development are outlined after the cases are presented.

6.2 Teaching argumentation in science

Initiating the kind of change that was attempted in Escalate was reliant on teachers trying out new approaches, sharing their experiences and reflecting on their own practice. The training programme for teaching argumentation that was developed grew out of previous research on teachers' use of argumentation in science classrooms (Simon *et al*, 2003, 2006) and from the in-service training materials called IDEAS (Ideas, Evidence and Argument in Science Education, Osborne *et al*, 2004b). The training programme built in expert inputs based on these materials, tasks using digalo, and sessions for sharing and reflecting on practice. A series of workshops was designed to incorporate these conditions.

Earlier work on enhancing the quality of argument in school science had focused on ways in which such quality could be determined. A suitable analytic framework used in previous research was based on Toulmin's (1958) argument pattern, which had been used as a basis for characterising argumentation in science lessons (Russell, 1983) and in other coding schemes (e.g. Jiménex-Aleixandre, Rodríguez & Duschl, 2000). Features of a Toulmin analysis of argumentation include: the extent to which students and teachers make use of data, claims, warrants, backings, qualifiers and rebuttals; and the extent to which they engage in claiming, justifying and opposing the arguments of each other. The Toulmin framework was therefore a feature of the way in which we helped teachers to conceptualise and evaluate argumentation. Previous work had led to a distinction being made between *argument* and *argumentation*, argument referring to the substance of claims, data, warrants and backings that contribute to the content of an argument, whereas argumentation to the process of assembling these components, in other words, of arguing. Through providing students with tasks that require discussion and debate, teachers can support students in the construction of arguments through the process of argumentation.

The IDEAS materials and previous work with teachers (Simon *et al* 2006) enabled us to plan the training to promote the following features of argumentation pedagogy:

- Articulate goals and a rationale for teaching argumentation
- Model and communicate the meaning of argumentation
- Develop tasks that incorporate the use of digalo
- Focus on the use of evidence
- Encourage counter-argument
- Evaluate arguments
- Become aware of their role as a facilitator

- Be reflective on their practice

The expert inputs began with sessions that helped teachers to become familiar with the rationale for teaching argumentation in science, in that for students to appreciate the origins of scientific belief and the nature of science they must explore some of the reasons why theories have become established and why alternative theories are considered to be ‘wrong’. Teachers discussed activities that invite students to evaluate the evidence that is used in such arguments, and became immersed (Loucks-Horsely et al 2003) in these activities themselves in order to appreciate their impact and extend their understanding of the possible teaching goals associated with argumentation. Many such activities were found in IDEAS, but teachers were also encouraged to find other resources, or to develop activities themselves to suit their own curricular schemes. Video materials and workshop sessions from IDEAS were incorporated that would help teachers to model argument and communicate its meaning to students. Video material was particularly focused on ways in which teachers could introduce argumentation activities, and support argumentation using oral prompts to help students justify their arguments with evidence, including playing ‘devil’s advocate’.

Exercises using Toulmin’s framework were introduced with the aim of helping teachers to evaluate argument. Teachers were encouraged to develop criteria for assessing the quality of students’ arguments focusing on how evidence was used to justify claims and how argumentation incorporated rebuttals. To encourage counter-argument, teachers were introduced to strategies that they could use to involve students in a conflict situation that can stimulate rebuttals (e.g. a pair taking one position in an argument works with a pair taking an opposing position). Teachers began their development of a case using digalo through identifying aspects of their science curriculum that could include an argumentation element.

6.3 Context for the implementation – the teachers

The statutory national curriculum for science in England specifies the content domains of scientific knowledge and understanding that should be included in the programmes of study for students from age 5 to 16. At key Stage 2 of the curriculum (age 7 to 11), most primary teachers are responsible for teaching all curriculum subjects with one class and may be able to adjust their schemes to suit scientific activities. However, many Key Stage 2 teachers and all Key Stage 3 (age 11 to 14) and Key Stage 4 teachers (age 14 to 16) follow school schemes of work that have very tight schedules and are inflexible. For example, a Year 8 (12-13 years) topic in a school scheme of work is typically designed according to 12 one-hour lessons (4 weeks) and must not go beyond this schedule. Science content changes completely from one topic to the next, for example, one month students are studying food, the next Earth and space.

All teachers working with us on Escalate had a duty to teach the schemes of work that were devised by their schools to meet national curriculum requirements. Activities that involved working with digalo needed to be incorporated into the scheduled lessons and timed to fit into prescribed teaching slots. Teachers could not spend more curriculum time on a topic than the number of lessons allocated. Moreover, computer rooms had to be booked in advance. Because each school devises its own scheme of work from the curriculum, Escalate contexts could only be determined for **each individual teacher** when the weeks they could participate were identified, when a digalo task could be fitted into the scheme of work at that point, and when that timing coincided with computer suite availability.

The first training workshop was attended by 4 primary teachers and 11 secondary teachers. All teachers expressed an interest in taking part in the project and using the Escalate tools. In the two months after the first workshop, however, not one teacher had tried out any of the activities. The second workshop was attended by 4 teachers, 2 primary and 2 secondary, who were willing to persevere and participate further. It was clear at this workshop that teachers needed far more individual preparatory work in the teaching of argumentation and use of digalo, so we decided to collaborate more closely with individual teachers to plan their cases and implementation. The teachers taking part were as follows:

Teacher A: from Kingsland School, a rural primary school with 256 students. The head teacher was supportive because he was responsible for improving ICT use in the school. The teacher was the science co-ordinator at the school and had been teaching for 3 years. She was keen to use digalo with able pupils aged 10-11.

Teacher B: from Sidford School, an urban community secondary school attended by approximately 1800 girls. Students have a wide range of ethnic backgrounds and a very high proportion speak English as an additional language. The school has science and mathematics specialist status and the teacher who used digalo was a science teacher who had been teaching in England for 3 years. The class using digalo was a high ability year 9 group (14-15 years) which included girls with challenging behaviour.

Teacher C: from Harrow School, an urban school with approximately 400 pupils aged 8-12. The teacher using digalo was an Advanced Skills Teacher of science and in a good position to use the software across the age range in the school.

Teacher D: from Greenway School, an inner city school attended by approximately 1350 girls. Four-fifths of students are from minority ethnic groups, a high proportion speak English as an additional language. The teacher using digalo was a newly qualified teacher of science, teaching a Year 8 high ability class (aged 12 – 13 years).

Once relationships with these 4 teachers were established, workshops took place on a total of 3 occasions over a period of 9 months, which allowed teachers to practice the digalo activities with students. During the workshops the research team initially acted as teacher trainers, providing inputs on argumentation and demonstrating digalo software. Collaborating partnerships were then set up with each participating teacher being advised and visited by one researcher. The role of the researcher in each collaboration changed according to the needs of the teacher. Teachers were able to feedback their experiences to others in the last two workshops and share their reflections on the success of their implementations. However they did not work together outside of the workshop venue.

The following sections provide details of each researcher/teacher collaboration, referred to as a Case Studies A, B, C and D.

6.4 Case A Kingsland: electricity

Overview of the case

A topic on electricity is included in the Key Stage 2 national curriculum. It builds on previous work on electricity and circuits in Key Stage 1. Children are expected to work with circuits, draw them, put them together practically and test them. A digalo activity was planned to be included in the last part of the scheme of work called investigating circuits. The teacher designed this case herself to fit in with the national curriculum, to engage able children in argumentation, to include ICT in science, and to practice her own skills in developing argumentation lessons using digalo in the process. An outline of the case is as follows:

- Modelling argumentation using digalo with an activity about funding a new zoo (IDEAS)
- Concept cartoons to generate discussion and explore misconceptions
- Digalo session making predictions
- Whole class teaching of electricity as part of the science National Curriculum
- Concept cartoons again with digalo – to add to the maps using a richer vocabulary from the electricity lesson
- Inquiry work on circuits
- Digalo again after making a black box and loading ammeter software
- New children in each group, final digalo session

The initial group of 9 children using Escalate tools had been identified as able achievers in either science or ICT and were from the teacher's own Year 6 class (10-11 years). In the last session a further 4 pupils joined in from another class. The 9 children involved had been active in a science club where they had engaged with scientific concepts to a greater extent than was possible in the general classroom situation. The teacher used constructivist methods in her teaching and the pupils were familiar with generating questions and group discussion in lessons.

The objectives and sequencing of the activities in this Case involved the use of concept cartoons (see Appendix 1) to explore children's ideas and then digalo to argue from conflicting positions. Evidence of knowledge outcomes could be identified through the way in which students wired circuits to test conflicting positions, as these were exposed through discussion of the concept cartoons, through their articulation of arguments related to these positions using digalo, and through the reasoned joint resolution of the initial conflict. Each group of 2 or 3 children used a different concept cartoon to stimulate discussion: thick and thin wires, long and short wires, street lamps. The children discussed the issues in small groups and came together to put forward their ideas to the whole class. They worked in their groups on the digalo maps.

Children were familiar with conceptualising and planning an experiment before doing their practical activity. They constructed circuits relevant to the concept cartoons and tested them to find evidence for their final digalo session. Each group was joined in this last session by a new member and the original group had to explain via Digalo how they had reached their conclusion about the correct interpretation of the concept cartoon.

Teacher's preparation and role
The teacher commented that her preparation for the electricity activity had not taken her long, largely because the children were developing the ideas themselves. All she needed to do was to provide a scenario from which an argument would ensue, ensure that children had enough knowledge to get started and that they had practiced sufficiently on digalo to get on with the task without technical problems. The preparation time was no longer than the normal time spent. By focusing on children in an out-of-class situation, the teacher aimed to stretch the learning of this group of children; in class they had not been able to argue in a more extended and developed way. She wanted to use concept cartoons in more depth, so that the children would gain more from them than is usual in a class situation.

The teacher wanted the children to work through arguments and practical activities until they came to their own logical and scientifically valid conclusion. Because this was an able group of children they could engage easily with digalo and could progress at their own speed. The teacher was able to interact with all the groups and stimulate children's thinking with argument prompts. She did not express her opinion but asked searching questions to encourage the children to think for themselves. The children added to their digalo maps as they reasoned their way through the questions she had put to them.

The teacher began each session with the concept cartoons and a reminder of what it was the children were trying to achieve, but she did not lead the discussions, the children put forward their own ideas. Neither did she impose her ideas on the development of the discussion. The teacher only intervened when she wanted to develop children's thinking along more productive lines or when she wanted them to consider how they would prove their claims. She did so by asking questions and not by telling the children "the answer".

Technical aspects
Whilst using digalo the children had no problems with choosing a shape, moving or placing shapes on screen, writing in the shape, using the arrows or taking turns. One pair suggested that, as the shapes filled the screen, there was a need for an automatic scroll down. These children did not use layers because it was a simple argument with no recognisable layers.

The limited number of computers was a major factor. Technical support was just adequate. A technician only visited the school once a week and took time to install the software initially. Two other issues were significant; first the programme had to be run on the administrator's login on each computer because there was no network. Second, the computers were old and saving to an external capture device (CD or USB stick) was impossible; the head teacher, who was the ICT co-ordinator, e-mailed these files to enable analysis. The map contributions could not to be printed at the school because there was no .txt software on these computers to save files to.

Analytical framework for arguments
It is necessary before evaluating the argumentation outcomes at Kingsland School to clarify the analytical framework, derived from previous studies drawing on Toulmin's argument pattern (Osborne et al, 2004a). The shapes that are available to use in argumentative maps are similar to Toulmin's argument components, allowing for cross-referencing between the maps and framework to take place, with some adaptations. The

following level system was used to assess the quality of argumentation from the digalo maps:

Level 1: Level 1 arguments are arguments that are a simple claim versus a counter-claim or a claim versus a claim, or easy questioning of a claim.

Level 2: Level 2 arguments consist of claims with explanations, comments, ideas, arguments or information that provide limited backing, or easy questions, but do not contain any rebuttals.

Level 3: Level 3 arguments consist of a series of claims or counter-claims with either explanations, comments, ideas, arguments or information that provide backing, or provocative questions, with the occasional weak rebuttal.

Level 4: Level 4 arguments consist of a claim with a clearly identifiable rebuttal. Such an argument may have several claims, explanations, comments, ideas and/or arguments or provocative questions.

Level 5: Level 5 arguments are extended with claims supported by explanations, comments, ideas, arguments and/or information, a series of answers to provocative questions and more than one rebuttal.

Analysis of the timing of digalo contributions was important because the teacher hoped that the children would change as they learned more about electricity. She also wanted them to progress in their learning of scientific concepts through their argumentation so arguments that showed the development of understanding of electrical circuits became a focus of the evaluation.

The implementation of the case.

The aim of the digalo activity in science at Kingsland was to stimulate argumentation in which everyone had an opportunity to put forward his or her own ideas about electrical circuits. As the activity progressed, the children were discussing circuits, adding to their knowledge and applying that knowledge as they engaged in practical lessons. Because they were using digalo the children also had a means of recording the development of their knowledge and the arguments they used to construct their understanding. The argumentation activity was with a group of 9 able children who were used to working together. At the beginning of the work on electricity the teacher asked for ideas about the circuits in their discussion of 3 concept cartoons Thicker wires (10.4); Longer wires (10.5); Street lamps (10.8) (see Appendix 1). These concept cartoons were developed from research on difficulties and alternative conceptions in this aspect of science (Naylor & Keogh 2000). The scientific understanding that the teacher hoped to develop is as follows:

Thicker wires: Children might decide that there will be more electricity flowing in a thick wire and so a bulb will be brighter. However, using thick wire in the circuit does not make the bulb shine more brightly. The brightness of the bulb depends on the resistance to the flow of electric current round the circuit. The limiting factor determining the flow of electrical current is the thickness of the filament in the bulb. Flow of electricity in thick and thin wires in a circuit can be investigated in practical experiments.

Longer wires: Children may suppose that if the wires in a circuit are long the electricity will take a longer time to go around the circuit and so the bulb will be dimmer than if shorter wires were used. Again, the limiting factor determining the flow of electricity is the thickness of the filament in the bulb. Flow of electricity in long and short wires in a circuit can be investigated in practical experiments.

Street lamps: Children may think that electricity starts at the power supply and goes to each lamp in turn in which case the lamp nearest the power source will be brighter than those further away. Electricity flows in each lamp at the same time and the lamps are wired in parallel rather than in series so that if one goes out the others remain bright. A circuit can be wired up in different ways to investigate the best way of wiring lamps so that they are all equally bright and remain on if one lamp fails.

Initial digalo session

The children had very little knowledge of electricity initially but, after discussion, each pair put forward ideas on digalo about solutions relevant to their concept cartoon. The following extracts how their ideas about electricity developed, have been coded according to argumentation components and evaluated using the level system. [*Throughout the examples are taken from the digalo maps without changes to spelling or grammar*]

The street lamp group's first attempt shows misconceptions about the power supply to the first lamp:

> **2 H? [claim]** All the lamps wil be equally bright
> **3 L? [claim]** The first lamp will be brighter
> **7 H [easy question]**Why do you think this?
> **8 L [backing for 3]** Because the electricity will reach the first lamp first so it will use more energy
> **9 H [backing]** But some of the energy from first lamp will be given to the other lamp

The group investigating thicker wire show their lack of knowledge and understanding and use misconceptions to back their claims:

> **1 M [claim]** the thikness of the wire does not mater. The thiner the wire the brighter the bulb
> **2 K [claim +backing]** if you have thicker wires going to the lamp it will be brighter
> **4 M [claim + backing]** The wire thickness does not matter because it could be plastic.
> **5 K [claim]** there will be less friction and more electricity.
> **6 M [claim +backing]** The only thing that can change the brightness is the length of the wire and the amount of components. Also more battreis would impove the power so the bulbs would be brighter
> **10 K [rebuttal + backing]** you are wrong because if you have a bigger wire there is more space for the electricity to flow

The group working on the length of wire in a circuit show the misconception expected:

> **5 S [claim]** There is more electric coming from the lamp
> **6 A [claim]** There is more electric going to the lamp

7 A [claim +backing] There is more electric going to the lamp because the wire is shorter
8 S [claim +backing] There is more electricity in the large wire because it can store more electricity
9 A [claim] The battery is closer to the lamp
11 S [easy question] What differnce does that make?
13 A [claim + backing] It takes less time to get to the lamp

Second digalo session

In the second session the children were better informed because the whole class had been taught electricity and everyone in the class had to wire up a simple circuit. The teacher had used the language associated with electricity in this lesson; power, wires, current, watts, amps, volts, and the components they added to the circuit and battery were a bulb, buzzer or switch. They learnt that the current was affected by these components in that they caused changes to the flow by adding resistance into the circuit. They did not take the science as far as measuring the current or looking at the differing resistance of various components because they had no ammeter at the time.

The digalo groups were encouraged to reconsider the concept cartoons, and discussed their new ideas in the light of what they had learnt in this whole class lesson. The group investigating street lamps now knew about circuits but they did not argue about the underlying science:

18 H [explanation] if i had a circit i could test it
20 L [easy question] How would you test it ?
21 H [explanation/backing] by reconstructing the circit used

There is no indication in the concept cartoon or what the circuit looks like in this instance so what follows is supposition.

22 L [provocative question] How could you layout the circuit so its like the lampost investigation?
23 H [explanation] by laying it out using the same equipment = 4 same bulbs, 1cell distance away from each other
24 L [provocative question] Yes but, Where will you put the wire, bulb and cell?

There must have been some dialogue here but the outcome is not recorded on digalo

28 L [claim +backing] You will need to put the bulbs in darkness so it is like the lampost because lamposts are turned on when its dark
29 H [explanation] I could put it in a dark box
30 L [provocative question] how would you measure brightness ?
31 H [explanation] with a light metre

The practical lesson also seems to have had little effect on the arguments developed by the group looking at thick wire in their second digalo session, except that they were newly aware of how to make a circuit:

12 M [provocative question] How do you know that it is better to have a thicker wire?
13 K [claim+backing] because the thicker wire allows more electricity to flow through.
15 M [provocative question] what would you do if you were making a circuit?
16 K [claim/explanation] i would have thick, short wire.
18 M [provocative question] can you explain more how if you had thicker wires it would be better?

> **19 K [claim/explain]** you could test a circuit with thicker wires and a circuit with thinner wires.

There is no elaboration regarding what might happen if this testing took place.

Practical sessions and further use of digalo

The following session included practical inquiry. At first the teacher encouraged each pair of children to identify the thicknesses of wire and the components they needed to put together a circuit that matched their concept cartoons. They also discussed what was revealed about the extra issues, in relation to the components of the circuit, raised in individual concept cartoons. For instance the length of the wire would have to be the same between the components even though they were investigating thickness of the wire; to vary the length of the wire would add another variable. For the same reason, in the street lamp circuit, all of the bulbs needed to be of the same wattage. When, in the street lamp circuit, one bulb was noticeably dimmer than the rest, the group tested it and chose another bulb so that the experiment was not compromised.

In the following session the groups took on different tasks; one group designed a black box that would hold a light meter and a bulb inside so that data regarding the difference in brightness of the lamps in the circuit could be collected. The children discussed the design and then made the black box using a partitioned shoe box painted back. An opening allowed access for the components and light meter but a black felt flap kept out the light once they were inside. Another group loaded the ammeter software and discussed how the software and computer interface would display their results; the ammeter data could be used to draw a graph when downloaded onto the computer. Other groups joined together to use digalo and consider what they would do to test the circuits.

The following extract shows how a group was uncertain about what to do and began the digalo session by noting the cost of the ammeter. When the teacher joined them she asked them to apply their knowledge of circuits to the testing process. This was a mixed group that added its comments to one side of the thick wire group's map and used the same 2 icons even though there were six participants, so no statement is attributable.

> **24 [claim]** The light meter would cost alot of money and would need time to master the skils of using it
> **26 [explanation]**But you need the two different circuit to make sure that the thickeness of the wires makes a difference
> **27 [provocative question]** which two different circuits would you have?
> **28 [explanation]**we would have the all thiner wire circiut.Which one would you have?
> **29 [explanation]** We would have an all thicker wire circuit.
> **31 [provocative question]** Would we have to use the same batteriy and same bulb to have a fair test?
> **32 [explanation]** yes because if the bulbs were different watts the brightness of the bulb would be effected. If you had a powerful battery and a weak one, it would not be a fair test.
> **33 [explanation]** We should use the same amount of wire as then the electricity would have to travel the same distance.
> **34 [explanation]** we could use a dark box to measure the brightness of the bulb

Final digalo session

In the final session the children were encouraged to explain their concept cartoon and experiment to newcomers. The new children were the gifted group from another class and were able to read the concept cartoon and the on-screen arguments before asking questions of the original pair. The aim was for the original pair to explain how they knew that the conclusion they had entered on digalo was correct.

The street lamp group concluded:

> **33 C [claim]** The light will be the same brightness. All the light bulbs will be equally bright as each other
> **36 Ch [easy question]** how do you know this?
> **37 H [backing explanation]** We built a dark box so we could measure the brightness of the light bulb

The length of wire group showed an understanding of the circuit and components and could explain their findings to a newcomer.

> **19 R [provocative question]** Is there more electric current in the wire
> **22 A [claim]** the electric current is the same in both wires
> **23 R [provocative question]** how did you find that out?
> **25 S [backing]** Because we used an AMM meter.
> **28 R [easy question]** what is a AMM metre?
> **29 A [backing]** A AMM metre is a tool that you mersure electric current in
> **31 R [provocative question]** ok.would it matter if the lamp had more volts?
> **32 S [claim+ backing]** Yes becuase it would take up more power in the wire

The thicker wire group did not make as much progress as other groups. Their initial idea was that the thick wire was the key factor in the flow of electricity in the circuit. Their practical experiment with the light meter could not have convinced them that the bulb was no brighter with the thicker wire than with the thinner wire.

> **36K [claim]** Our results showed us that the bulb was brighter with the thick wire.
> **37 F [easy question]** What equipment did you use?
> **39 M [explanation]** Wire,bulb,light meter,dark box and batteries
> **40 F [easy question]** How do you use a light meter?
> **41K [explanation]** You put your circuit in a dark box, then you put the light meter in with it and you wait for your result.
> **42F [provocative question]** HOW DO YOU KNOW YOU ARE RIGHT ???
> **43 K** because….*statement unfinished*

Students' engagement

Most children's oral and digalo contributions were relevant to the subject. Each group began with an initial set of arguments based on their first encounter with the concept cartoons. Although relevant, children's comments demonstrated limitations in the use of scientific language e.g. the use of the word friction instead of resistance. Initially the limited scientific vocabulary made some of the arguments seem illogical but the pupils were asked to defend their ideas and they did so despite having limited knowledge of electrical circuits. The children were used to modelling and were capable of putting an electrical circuit together to test the claims put forward in the concept cartoons.

Children developed their arguments after the whole class lesson on electrical circuits and after they had engaged in practical construction of circuits. They all added to their digalo maps, which show individuals changing their ideas on the same map over time. It was not until the whole class had explored the subject with the teacher that more relevant comments were added to digalo maps and the use of scientific language improved. The final maps reflect further progress because children had to express their ideas clearly to another pupil. By answering the newcomers' questions children clarified their understanding of the argument already set out on digalo and in the practical testing experience. The new participants had also studied electricity (in a different class) and had some grasp of the concepts being discussed. The teacher questioned the new children about their understanding of the group's thinking on the concept cartoon and circuits.
In the interviews after this series of lessons, the children involved said that they liked working with digalo and they had told others about it who now wanted to work with it too. The teacher suggested that using digalo could have been a whole class activity, with better computer facilities. She thought lower ability groups would have enjoyed working like this but would not have developed their thinking in the same way. Those with poor reading and writing ability would not have participated in the same way. They would have needed a lot more support.

Social interactions
The groups of children were used to working together and were well-motivated; recorded data showed a minimal level of irrelevant discussion. The children concentrated on the task, took turns with digalo and listened to each other. The discussions were open and the children could make any comments that they thought relevant. In one pair, a more able child took on a role of opposition to encourage the other child to argue for a more justified point, and he had to maintain his position until he felt that the evidence provided was sufficient.

The final arguments were a joint effort, each child had contributed and the teacher had asked questions that made them think more deeply. The argumentation was not complex and there was only one outcome for each of the arguments presented in the concept cartoons. A joint resolution was not difficult to obtain.

Because the children worked in the small select group they collaborated well; it was an easy group to manage. The teacher was happy with class management because the children were motivated to work together. She thought that a whole class doing group work with digalo would have been easier than usual discussion lessons because their work and their thinking would be displayed. It would be easier to stand back and only add to children's ideas when they asked for help or when the arguments on screen showed that the discussion was diminishing.

Evaluation discussion
The teacher was concerned that this gifted group had an opportunity to develop argumentation skills. She wanted to push them to extend their thoughts and create ideas from other people. The children had used the equipment in the whole class lesson but the teacher wanted them to think about different circuits with a greater range of components and wires. She wanted them to take their practical work as far as they could to really

understand the limiting factors. Reflection over a period of time was possible with this group and the teacher wanted them to think much harder as a result and develop their conceptual understanding. Digalo was used to allow them to see any mistakes they had made and move their thinking forward. Motivation, discussion, listening, collaboration and sharing of thought processes were all goals for the experience with Digalo.

Because the teacher was more interested in constructing subject knowledge rather than argumentation skills, she did not attempt a formal introduction to what an argument is or how to construct an argument. She had configured the digalo tool with a broad range of options; Claim, Information, Argument, Question, Comment, Idea, Explanation although the only shapes used repeatedly by most groups were Claim, Argument, Question and Explanation. There was no consistency in their use either within groups or between groups. See figure 1.

Figure 1. Use of configured shapes on Digalo

Group	Claim	Information	Argument	Question	Comment	Idea	Explanation
Street lamp	2	1	10	7	0	0	5
Long/short wire	2	0	5	5	0	0	8
Thick/thin wire	2	2	6	10	0	0	5

When the children began to use digalo the teacher explained how to start; that one person sets out an argument and the other provides a counter argument. The teacher reminded them that if they were supporting or opposing points that they should use the linking arrows. She suggested that if they were providing an explanation it should go into an explanation shape. Because the children could edit the shapes, she suggested a change of shape to several children if, for instance, they were not putting an explanation in its appropriate shape. She did not clarify use of the shapes on the digalo toolbar further except when she asked in the last session that the conclusion be put in an explanation shape.

By giving the children a broad range of options on the digalo toolbar they could interpret them as they wished which probably explains why one group had 10 information boxes and another had 8 explanation boxes. All groups used only 2 claims, those at the beginning of the argumentation activity. During the analysis it became evident that as the children created arguments they did not always change the user, which made analysis problematic in places.

The name of the contributor, the linking arrows that are used and the timing of arguments created on the maps are important for analysing the level of argumentation. The maps provide sufficient evidence of the level of understanding in any one argument and the interaction of the contributors affecting the arguments presented. There is some evidence too that group members shared their understanding with each other and those with practical capabilities informed those with better conceptual understanding. Those who expressed themselves well could articulate arguments more clearly, which benefited those with a poorer vocabulary.

In the following example H and L were the original pair discussing the street lamp concept cartoon. C joined them in the second session and Ch joined them in the last session.

The initial claims cannot be attributed because the children did not pick a user. (Street lamp 1)

2 facilitator [claim] all the lamps wil be equally bright

3 facilitator [claim] The first lamp will be brighter

7 H [easy question] Why do you think this?

The initial claims are backed up by some poorly expressed arguments.

8 L [claim + backing] Because the electricity will reach the first lamp first so it will use more energy

9 H [claim + backing] But some of the energy from first lamp will be given to the other lamp

11 L [claim+ backing] some of the left over energy that is not used will reach the first lamp

12 H [easy question] But is it more left over

13 L [claim + backing] The left over energy will keep restoring so the process will keep on going around so the first lamp will keep on receiving the energy first.

14 H [claim] but the energy have hardly eny time with the first lamp

15 L [claim] So that is why the first lamp would recieve more energy

At this point H realises that L is wrong but he has no arguments of his own with which to convince him so he changes his strategy and starts to ask questions instead.

17 L [easy question] How can you prove it ?

After this initial session the experience of the whole class practical lesson, in which they made a circuit, alters the arguments radically. L still has no real grasp of what happens in the street lamp circuit but he ceases to try to explain his views and asks his partner to explain his thinking. He draws out explanations.

The second session began here: (Street lamp 2)

18 H [explanation] if i had a circit i could test it

20 L [easy question] How would you test it ?

21 H [explanation] by reconstructing the circit used

22 L [provocative question] How could you layout the circuit so its like the lampost investigation?

23 H [explanation] by laying it out using the same equipment = 4 same bulbs 1cell distance away from each other

24 L [provocative question] Yes but, Where will you put the wire, bulb and cell?

28 L [claim +backing] You will need to put the bulbs in darkness so it is like the lampost because lamposts are turned on when its dark

29 H [explanation] I could put it in a dark box

30 L [provocative question] how would you measure brightness ?

31 H [explanation] with a light metre

The third member of the group, who contributed nothing to the foregoing exchanges about practical issues, was able to articulate what using the ammeter would show.

33 Con [claim] The light will be the same brightness. All the light bulbs will be equally bright as each other

The construction of the circuit in the third session and the measurement using the ammeter and light box resolved the question of the distribution of current around the circuit and how it affected brightness of the street lamps. H and L designed the black box with which to test the brightness of each bulb in the circuit. The test in the fifth session using the light meter in the black box to test the bulb brightness and an ammeter enabled the children to measure the current. The data allowed conclusions to be drawn. The last session included the newcomer who read the arguments, including Claim 33 which explained the resolution of the concept cartoon. The newcomer then asked questions which the practical session helped the original group to explain. (Street lamp 3)

> **36 Ch [easy question]** how do you know this?
> **37 H [explanation]** We built a dark box so we could measure the brightness of the light bulb

The digalo maps mostly show progression in understanding as arguments were added over the 4 sessions.

The levels of argumentation were determined using the analytical framework described above. The street lamp group achieved a level 2. Their argumentative map shows that this group had a poor initial grasp of the topic, derived their understanding from the practical session and were able to express their ideas once they had completed the hands-on experience. The thin/thick wire group's map was difficult to assess. Although this group included rebuttals and explanations, the conclusion shows that there were still misconceptions and the newcomer tried to make the group explain more fully why they reached their conclusion. It is a level 3 argument in terms of argumentation processes but from the content point of view is low level because the initial claim was not changed. The long/short wire group achieved a level 2 argument because there were no rebuttals. The level of the argumentation does not reflect the real effect on learning or understanding this whole activity had on this group. The evaluation of argumentative maps using the analytical framework only provides information about the argumentation process; advances in scientific understanding have been assessed by the robustness of scientific ideas when exposed to cross-questioning by peers. Digalo has provided the platform for enabling this dialogic experience.

Examples of Children's Learning outcomes

The teacher's initial aims were to stimulate argument so that children would then put forward their own ideas, add to their knowledge and apply that knowledge. She was aware that digalo provided a different way of showing learning and that some children would respond better than others to this new method. By using digalo, all participants had to articulate their understanding. Because all of their arguments were displayed on the pad map throughout, individuals could go back over what they and others had said and could relate it both to the concept cartoons and the circuits they had constructed and tested. In one of his few contributions to the street lamp argument, this boy shows his understanding of the problem in the concept cartoon:

> **33 Con [claim]** The light will be the same brightness. All the light bulbs will be equally bright as each other

Explaining the issues to a newcomer also revealed understanding although much of this was done orally rather than on digalo. In this example the ideas are the children's own even though the teacher is drawing them out with her questions:

DR 17.46 L: We now know that thicker wires are better because they have less resistance.
Teacher: You now need to ask some questions A, why do they know that, how have they found out.

The children say that they have told him that they did experiments

T**eacher**: Well that doesn't tell you much does it A? So what experiment did you do? What did you actually do?
Tr: Well we had 2 different circuits.
Teacher: Ah well A needs to find out don't you, so you need to ask another question.

Students were encouraged to focus on the concept cartoons and the different explanations given in them. Critically examining the points raised initiated reasoning rather than guessing. One of the least able girls in the group began with this claim because she thought there would be more electricity going to the lamp through the short wire:

6 A [claim] There is more electric going to the lamp

Later she recorded:

22 A [claim] the electric current is the same in both wires

Her understanding had been affected both by her partner's arguments and the activities during the practical sessions

Digalo allowed children to present their knowledge and to co-construct knowledge and understanding as they committed their thoughts to their chosen shapes. Visualizing argument was effective because the children's comments were mediated by digalo, and children were prompted to think of replies to points that they saw displayed, so they expressed and clarified their ideas on screen:

20 L [easy question] How would you test it ?
21 H [explanation/backing] by reconstructing the circit used
22 L [provocative question] How could you layout the circuit so its like the lampost investigation?
23 H [explanation] by laying it out using the same equipment = 4 same bulbs 1cell distance away from each other
24 L [provocative question] Yes but, Where will you put the wire, bulb and cell?

All of the children learnt about electricity and this was the first time they had made circuits. Here they had to use their knowledge and apply it to the concept cartoon and then construct a compatible circuit and test it for themselves. Rather than just disgorging everything they knew about the topic they applied their knowledge and were able to explain what they had done to a newcomer:

22 A [claim] the electric current is the same in both wires
23 R [question] how did you find that out?
25 S [backing] Because we used an AMM meter.
28 R [question] what is a AMM metre?

29 A [backing for 25] A AMM metre is a tool that you mersure electric current in

and

12 M [question] How do you know that it is better to have a thicker wire?
13 K [backing] because the thicker wire allows more electricity to flow through.
15 M [provocative question] what would you do if you were making a circuit?
16 K [explanation] i would have thick, short wire.

M is not happy with this explanation and goes on asking questions:

18 M [provocative question] can you explain more how if you had thicker wires it would be better?
19 K [explanation] you could test a circuit with thicker wires and a circuit with thinner wires

Evaluation of the Teachers' Learning

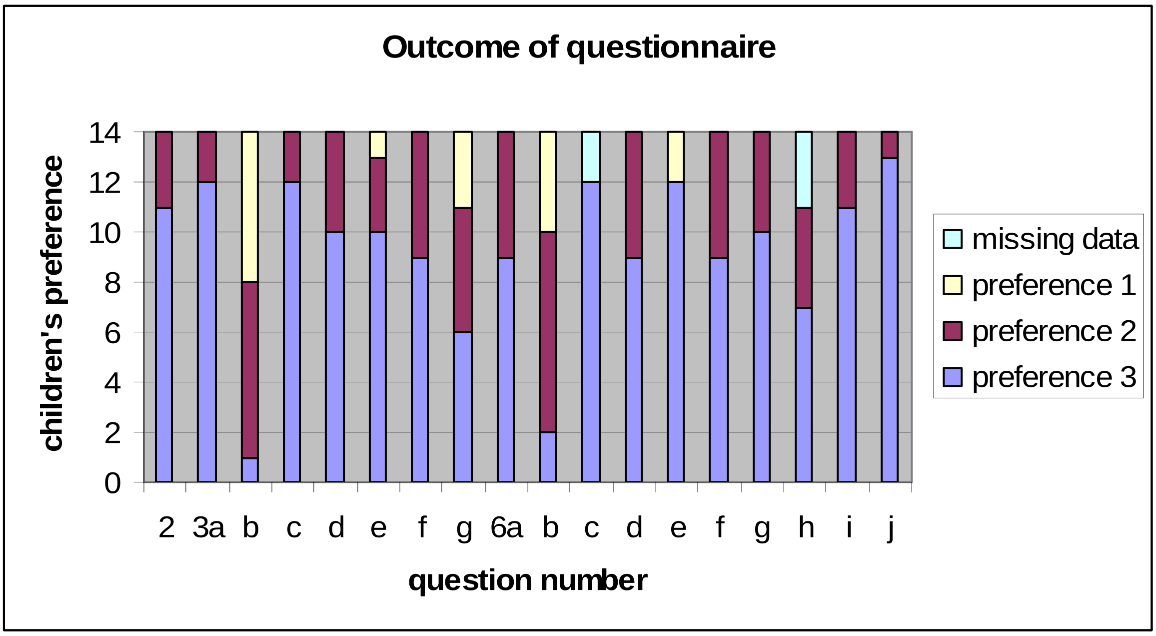
The implementation of digalo by this teacher indicated something about her values; it expressed her forward-looking practice and the importance she attaches to student centred learning. Ensuring that students worked together and triggered exchanges amongst themselves was her main aim. She provided analogies and modelled argument to encourage participation. Being able to prompt children to commit their arguments to the digalo map and to make a circuit that replicated those in the concept cartoon were important here because these activities affected learning outcomes. Guiding pupils and asking new questions as they moved their arguments on meant that the teacher had a flexible role that changed as the argument progressed.

This teacher was well prepared for the topics the pupils might introduce into the argument. She was also aware that in teaching others, pupils would clarify their own ideas and so the strategy of introducing a newcomer to each group in the final session was a good one. To enhance levels of argumentation, more thought might have been given to configuring digalo. Since this was the first time the pupils had used the tool a smaller number of options might have allowed arguments to be better structured. The digalo configuration the teacher provided was not very helpful for seeing similar argument structures in different groups. Some used opposition arrows as a sign of disagreement and only one group typed in rebuttals. Some used explanation boxes while others opted to use the information or argument shape for similar content. By applying the Levels of Argument framework to the texts from digalo the teacher would be able to determine how best to move children on in their reasoning and structuring of arguments. She will need to do more work on the argumentation process rather than hoping the children will begin to understand the structure of an argument through the content they are arguing about.

Evaluation of affective outcomes

Results of the questionnaire (Appendix 2) administered to 14 children after further digalo activities at Kingsland School are shown in Figure 2.

Figure 2 Results of the students' questionnaire at Kingsland School.



The majority of children really enjoyed working with digalo and they liked using computers in science. They preferred not to use pencil and paper in science lessons and they liked to work in groups. This was an able group and so it is not surprising that most liked having to think of their own ideas; 10 out of the 14 liked to argue with others and having to say what they thought. Fewer than half were enthusiastic about writing what they thought.

The children's comments about the use of digalo included:
"I learned to try and see past the question."
"How to develop my own ideas."
"it helped [me] to understand the topic"
"how to discuss problems and how to handle arguments"
"we now can communicate much easier"
"we can compare our ideas"
"we had to discuss things and work as a group"
"it was a good way of recording results"
"it made me more confident in science and talking to people"
"we were discussing our ideas and talking about them".

Nine children thought that using digalo made them more interested in the topic and all but two said that digalo made them really think about the important points in the argument. Nine children weighed up evidence using Digalo and the majority learned more facts as they discussed the topic. Ten said that Digalo helped them to develop their own ideas but only seven said it helped them to think about the next argument once they had made a point. The majority showed that Digalo helped them to understand what an argument is.

Asked *Why do you need to argue about topics in science?* there were a range of ideas which included:
"because people have other ideas";
"the more your ideas are correct";
"so you can explain the main points in a fun way and discuss ideas";

"to give you evidence against the topic or with the topic";
"because it helps you to develop and discuss your own points of view";
"so you can see different points of view and you can reach what is the right explanation";
"to discover different views and more points of view";
"because it helps me to understand the experiments we do better";
"so you can come to a conclusion about something";
"to prove which is right".

This evaluation demonstrated very positive effects of using digalo in this school context.

6.5 Case B Sidford: energy

Overview

The digalo activity at Sidford was part of a revision exercise before national tests for year 9 pupils (13-14 years). The teacher's intention was to encourage argumentation so that students were better able to answer questions that raised opposing points of view. Challenging behaviour was an acknowledge problem with this class but the teacher wanted them to have an opportunity to engage in argumentation and to use ICT to do so. She had initially used an activity from the IDEAS pack which asked students to consider what an argument was. They saw it as war and confrontation and even though she explained what a scientific argument was some still said they had won when their digalo activity ended.

The teacher used the energy exercise from the IDEA resources. In it a problem is set: settlers have to find a source of energy for their island because there is no other means of energy provision. The subject content relates to alternative fuels available to the population of this island. The arguments constructed concern the advantages and disadvantages of each fuel source in this isolated island context. Each student was given an evidence card and the information on these cards gave them sufficient information to take a specific position on one energy source. Those with the same energy sources had a discussion in this first lesson. The teacher also asked the students to write their own set of advantages and disadvantages for all of the energy recourses in this lesson; hydroelectricity, wind, solar, coal or nuclear power. Their homework was to find out more about energy source for the digalo lesson. Although this was an able group, students did very little research so the teacher provided the evidence cards again in the digalo session. The student then went into new groups to work on digalo; each was the expert on their source of energy in a group of 5 energy sources. Digalo was set up on 5 computers each with 5 card options on the tool bar: claim, information, argument, question and explanation.

The teacher's role

The teacher had prepared evidence cards for these lessons, worked with the students on what they thought it meant to create arguments and asked them to consider and record the advantages and disadvantages of all forms of energy under discussion. She had organised the students so that they researched one energy source in non-friendship groups and then reallocated them to groups in which all energy sources were represented. She was well organised and in her interview said that she had spent about 2 hours preparing for the 2 lessons which included one digalo interaction.

During the digalo activity the teacher observed the groups as her objective was to check that students had put themselves on as users and that digalo was working well on the computers. She was diverted for part of the lesson when digalo froze on one group's computer and she had to open it for them on a different computer. As a consequence, her input into group discussions was minimal.

The teacher later commented that the groups of 5 were too big for a good digalo session. There were 8 computers available so group size could have been reduced and smaller groups might have encouraged more collaboration. Published resources can impose inflexibly and the need to be flexible was particularly relevant in the light of the computer availability and the disposition of the class involved.

Student engagement
The students were in groups that each represented their own source of energy. They were then shown how to use digalo and began to argue for their energy source within the mixed group. They were happy to use digalo and were able to work on it immediately.

It was unfortunate that the grouping had conformed to the IDEAS model because it imposed a structure in which 5 students tried to take turns and add information to one digalo pad on each computer. A comparatively long waiting time to make a contribution allowed students to be distracted by the video camera or their own conversations.

Some members of each group took the activity seriously and worked reasonably well with digalo. The noise level in the room during the activity was such that the video and voice recorders picked up very little from individuals so the discussions that went on were almost inaudible. The advantage of using digalo is that a synthesis of students' input is still seen on the pad maps.

In Groups1 and 2 all five students contributed but in group 3 only four contributed. The other groups failed to save their maps so there was no way of analysing how they interacted or their level of engagement. For those who did save their digalo maps, these provided an insight into their understanding of the problem set, the subject content and how they constructed arguments.

The students were shown arguments relevant to energy sources at the beginning of the activity and how these arguments were linked. Each model argument had backing and there were examples of rebuttals and questions. They paid attention to this part of the lesson but it was evident from their digalo maps that they had no real understanding of how to create arguments themselves.

Group 1 began their argumentative map with a claim made in an information shape; there was uncertainty about the meaning of cards on the toolbar. Contributions that followed were truncated with no development e.g. "Solar energy is best." Not until the 6th contribution was there some development of a claim with information to back the assertion: "nuclear is better because a little amount of nuclear fuel makes a lot of electricity".
There were references to cost, output potential, pollution and sustainability but in no depth and with no reference to finding the best source of energy in the context of an isolated island.

Students added more detail towards the end of the activity but the final comment sums up the general lack of knowledge. “How do you [know] that this has a long term damage of waste leaking into the environment? Have you done all the research to support this?”
On the map, counter-claims are linked with opposition arrows but there is little development of arguments in favour of their own source of energy within a contribution opposing other energy sources for this context. It is also evident from the content of each card that it was written by a different user but the students forgot to change user so it was difficult to attribute comments on the map to individual students. Using the same analytical framework described in the Kingsland case study, this is a level 2 argument.

Group 2 had a much fuller argument with longer contributions and more backing for points made. There was still a problem with identifying the contributor for each argument because the user was not changed but as a group they had oral discussions during the activity and were quite involved compared with other groups. Their arguments contained several clearly identifiable rebuttals and counter claims, but the rebuttals were weak and *it* is used instead of the energy type and so the source they are referring to is ambiguous. To some extent they included comments on cost, output, pollution, sustainability, effect on local wildlife of creating a reservoir, flexibility and reliability of supply and the ugliness of wind turbines. There was also reference to the context and reason for finding the best source of energy. Using the same analytical framework described in the Kingsland case study, this is a level 3 argument.

Group 3 provided short statements and weak or poorly expressed arguments to back their claims e.g. “I still don't think its the best energy because the sun isn't always there.” It is evident from the map that individuals changed each other’s contributions during the activity. There is a 6 minute time gap and the contribution is attributed to Nichaela in the first instance and Sharmalee in the second. The underlying meaning is the same but the wording is improved.

> **ID : 7**
> Title : I don't think coal is the best enrgy because it is not reliable and you can't using it for long
> Type : Argument
> Creator: Nichaela, Date : Tue Mar 20 09:59:06 GMT 2007
> Modifier: Nichaela, Date : Tue Mar 20 09:59:06 GMT 2007
> Link : Opposition from 7 to 5 set by Sharmalee

> **ID : 7**
> Title : I don't think coal is the best enrgy because it is not renewable
> Type : Argument
> Creator: Sharmalee, Date : Wed Mar 21 15:10:23 GMT 2007
> Modifier: Sharmalee, Date : Wed Mar 21 15:12:03 GMT 2007
> Link : Opposition from 8 to 7 set by Leisha

The whole argument was difficult to analyse because this is one of 3 such changes out of the 10 contributions made in total. Using the same analytical framework, this argument is level 2 and it does not touch on the context of the problem. In their justifications the students introduced pollution, cost, maintenance, and reliability to some extent for their particular energy resource but only in an all-purpose context.

The print out from each group showed how they constructed their arguments.

The students used cards in the following way.

Figure 3 Use of cards configured on digalo

Group	Claim	Informatio n	Argument	Question	Explanation
Group 1	5	2	8		1
Group 2	10	1	3		1
Group 3	6	2	4		1

This was their first engagement with digalo which may account for the range of cards used for simple claims. Although the teacher had talked to this class about what an argument was she did not introduce argumentation structure and the students were given only a brief introduction to digalo that showed how an argument could be constructed using the toolbar shapes.

The digalo activity was not integrated into a series of lessons. The lesson in which argumentation was introduced was not matched by a follow up lesson in which students could evaluate the content of their arguments. Neither was there time for reflection on the process of argumentation. Revision of science content was the aim of this lesson but the maps show that the students had a superficial understanding of energy sources and, with the exception of one group, were unable to apply what knowledge they had to the situation in a new context.

Affective dimension

The teacher did not put the students into friendship groups for class management reasons but she felt that they collaborated well in their allotted groups and were better motivated than usual. In her interview she noted that one very shy girl was more involved than in normal lessons.

Technical aspects

Technical assistance was good in this school and digalo was set up well before the lesson. However, once they had opened their computers, the students had to work through 10 actions to get to their digalo pad and start adding each user. Once they had started the teacher was pleased with how quickly the students were able to work with digalo.

For some reason during configuration the teacher, who lacked confidence generally in using IT, had made the default size of text boxes very small and so the students had to resize every contribution they made. The students had difficulty saving their maps, probably because they had to go through 5 actions to get to the file allocated to them. Even with technical assistance, digalo files for 2 groups could not be found on the school system after the lesson.

Evaluation discussion

The stimulus for an argument is important because the topic can motivate or deter engagement. The case at this school was a revision exercise and the topic would have been useful to the students if they had understood that they needed to use the information in the stimulus material to come to a conclusion regarding a particular context. Weaker pupils did not go beyond the energy information they had been given and they did not develop their own ideas based on this scenario of the islander's dilemma. Although the students were asked to do research before the digalo session, few did and so produced fairly weak arguments with little support of justification.

The teacher hoped to encourage precise questioning but arguments were mostly simple with little refinement of meaning or clarification of understanding of the main issues on the digalo maps. There was no time for reflection on the arguments and how students might have used their information to prove their claims and apply it to the context they were given.

There was little co-construction of knowledge although there was some evidence of application of knowledge even if it was just re-stating the information provided. The language of scientific argument, listening and responding to others was limited.

Examples of student learning outcomes
It is difficult to judge the learning outcomes for students from this lesson. Those that made the effort to do some research and participate in the argumentation were learning various skills. By using digalo, all participants had to articulate their understanding and their arguments were displayed on the pad map. Developing understanding through argument could only take place in those groups where arguments were more fully developed and questions were asked that provoked others to clarify their meaning. Digalo allowed students to present their knowledge and to co-construct both knowledge and understanding as they developed their reasoning about different energy sources. Their knowledge was limited:

> **Grp1 17** How do you no that this has a long term damage of waste leaking into the enviroment? have you done all the research to surport this?

Such a provocative question could have drawn out more arguments but it came at the end of the lesson and there was no time for replies. Previous contributions had been brief and simple claim and counter claim with no development at all. Group 3 is the only group that understood that the energy source chosen would need to meet specific criteria but was not chosen because one expert said that their energy source was best without justification and precise support.

The teacher had prepared information about the topic and wanted the pupils to clarify their own ideas as they exchanged arguments. To achieve specific learning outcomes, more thought might have been given to configuring digalo with a smaller number of card options to allow the whole argument to be better structured. The teacher had provided evidence that supported different points of view but the students not only had to apply this information to a specific context but also work in an unfamiliar way. Understanding with the argumentation process and working with digalo for the first time was too much to expect of some students and the expectation for the outcome of this activity was too high.
The teacher needed to do more work on the argumentation process rather than hoping the students would begin to understand the structure of an argument through the content they argued about. Starting to use digalo with science classes in earlier years would make it easier for Year 9 students to construct arguments. Poor scientific language skills were also evident from the digalo maps. The students needed more practice at listening to and arguing against others.

6.6 Case C Harrow: McDonald's

Sessions were not observed here, but an extended interview with the teacher after a series of digalo sessions, and resulting argumentative maps, formed the basis of this evaluation.

Overview

The teacher involved was an Advanced Skills Teacher who worked with all classes in this middle school (8 to 12 years). To explore the use of digalo he initially conducted 35 minute sessions with groups of four children from four different year groups. Each group included two girls and two boys of mixed ability. The teacher believed that some of the children would struggle with argumentation, however he asked the class teachers to select four children who were capable of contributing well and who would express an opinion even if they thought it was wrong. The children constructed maps based on argumentation about the value of McDonald's fast food.

In a further digalo session the teacher worked for an hour with a combined group of children aged 8 to 10 years, the focus was on electricity. Year 4 children (8-9 years) had just started learning about electricity but year 5 children (9-10 years) had experienced no more teaching on electricity since they were in Year 4. The teacher had never used a concept cartoon before but chose to do so here and introduced one which depicted three children looking at a very simple circuit of a battery, switch and a bulb. The children discussed where the components should be placed and what differences the various positions might make. The teacher asked the children to think about the concept cartoon and gave them 15 minutes to write their initial thoughts and predict what might happen, using digalo. The children then made the circuit, after which they went back to digalo to record any changes they had decided upon and to add evidence based upon the circuits they had constructed. The teacher observed that, because they had not used the electrical kits before, they did not collect as much information as he expected so could not include much improved knowledge in their second use of digalo.

The teacher went on to work with a whole class of year 7 (11-12s) using laptops. None of these children had used digalo previously but the teacher wanted to try digalo in a whole class situation. He prepared an activity based on what they thought was best about Harrow School. The aim was to do this non-science activity and then use it to model how the children might apply the same ranking to energy sources. Although the students started to use digalo well, the teacher found that they needed support on how to construct arguments because none of them had really talked about it before. There were also technical problems that resulted in the session being limited.

Social interaction

The teacher thought that the digalo activity worked well socially. He noted that those who benefited least were the children who typed in the contributions and remained on the periphery of the interactions. The majority of the children engaged well with each other and had discussions before they typed because they didn't actually want to commit it to the computer. Together they helped each other to make changes. They also asked as a group whether they should change the boxes e.g. make the card an argument card rather than evidence cards.

The teacher made the point in the McDonald's activity that he was encouraging the children to think about the opposite points of view and read what others had written.

There was good collaboration. The teacher suggested that the students learned the language they used from each other and when they looked at each other's maps and saw the words salts and fats, they used those words. He thought that a teacher using the same words would be ignored, whereas seeing another child use a word made others want to use it. The teacher had insufficient time to sit with all groups for more than a few minutes in a lesson to probe their reasoning. Children were asking each other open questions in the digalo activity and the teacher thought this was helpful in drawing out knowledge and better thinking.

Teacher's role

The teacher thought that his role had not changed and that he often put emphasis on the process of justification in science. He thought that doing some work, coming back to it and getting students to look at each other's work to learn from each other had merit. He thought that digalo supported this approach and in a way that was unthreatening. He also saw digalo as a means of introducing differentiation in terms of the contributions children made rather than being given differentiated texts and so children felt that they were starting from the same place. Working in this way the teacher felt that he was enabling and facilitating learning. All of the groups had the same toolbar configuration whatever their age or ability, the teacher also configured the toolbar so that the number of cards was appropriate to the lesson.

As he toured the classes this teacher found that he was asking many more open questions about their work, 'why did you put that' 'what could you link it to next'; encouraging rather than telling. He thought that others might be given the opportunity, if they used Digalo, to work in an open way and allow students to evaluate their own thoughts on a subject. More student-centred instead of teacher-centred lessons would, he thought, mean teachers changing their attitudes to time limits and subject content and emphasising instead justification of ideas and sharing thoughts. He illustrated this point with the McDonald's activity in which a year 4 group was talking about fats and salts without prompting and offering sophisticated arguments using scientific language. It surprised him that the language came up naturally rather than him having to give it to the students. The teacher had some difficulty with the language of argument construction e.g. can a claim be an argument at the same time? He thought that, in hindsight, it was important to be very clear and to model one of the arguments to explain to children what the labels on the cards meant or at least making the children think about the construction of their arguments.

Technical aspects

The students had difficulty saving the Digalo maps. They also had difficulties when opening the school wireless network with Digalo; it took 35 minutes for everything to open. The teacher had no explanation for this problem but thought it was not the school network that had a problem (others were using it at the same time). Instead of using a pad he had prepared, the students all started with a blank pad which was less than ideal. He thought that using 16 laptops using the same programme had caused the problem. Changing icons for users also caused the programme to freeze. There were issues of accessing the files to start a digalo session. The way folders are all set up in this school means that students have to go through many actions to reach the right file to open and then again when saving.

The teacher was happy with the changes to pedagogy that using digalo could bring but he thought that the lack of technical expertise was a barrier to doing so. Students on the other hand were technically adept and technology was no barrier to them and need no teaching to "whizz" through.

Evaluation discussion

The teacher had set up the pad maps for the children but they could not change the names he allocated because the computer crashed if they tried to do so. The consequence for any analysis is that the identity of a child making a contribution is unknown both on the maps and the printed texts of contributions.

The teacher used the same computers for all of the groups taking part in the digalo activity. Between group-work in any one activity the teacher deleted all of the previous contributions although he left the original statement each time on the digalo pad. When the contributions from the maps were printed, all were shown together. Although the timing was available for each contribution, these composite maps were difficult to analyse especially when all of the contributors were identified as pupil 1 and pupil 2.

<u>Example</u>

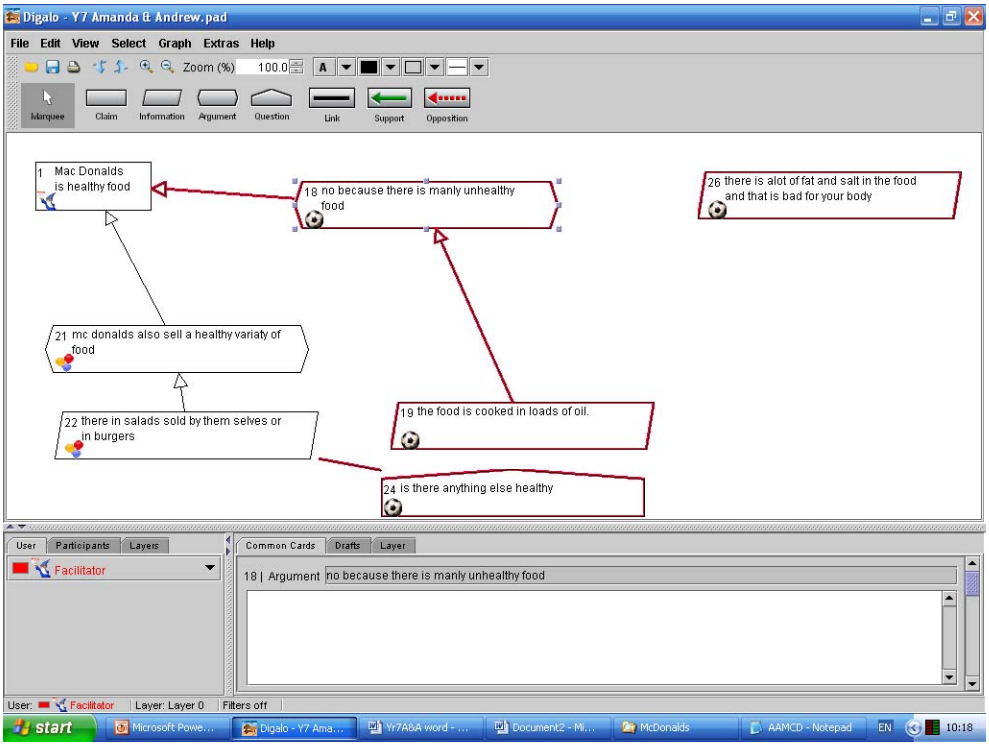
McDonald's case

Contributions recorded on the print function for one computer

ID : 1 McDonald's is healthy food 09:38Facilitator
ID : 2 Yes it is because the kids meals are healthy Pupil 1 11:15
ID : 3 Not necessarily all chips and burgers contain a lot of oil Pupil 2 11:16
ID : 3 McDonald's is not healthy food Pupil 2, 11:16
ID : 4 I think it is healthy because McDonalds has meat which is a protein to keep you healthy and strong 11:19:35
ID : 5 McDonald's is not healthy because the chips have bad oil in them Pupil 1, 11:22:02
ID : 6 Have you been their to know if the food is healthy or not Pupil 2 11:24
ID : 7 yes it is Pupil 1 11:26
ID : 8 they use carrot sticks instead of chips Pupil 1 11:30
ID : 8 because it tastes nice Pupil 1, 11:30
ID : 9 Whose gonna Pupil 2, 11:32
ID : 9 no its not healthy 2, 11:32
ID : 10 its fattening Pupil 2, 14:03:30
ID : 11 How much fat do you have to have in food to say its fattening Pupil 2, 14:04
ID : 12 How much fat do you have to have in food to say its Pupil 1,14:06
ID : 13 just because it tastes nice does it mean it is healthy? Pupil 2, 14:07
ID : 14 a treat once in a while Pupil 2, 14:08
ID : 15 a treat once in a while doesn't harm you Pupil 1, 14:09:15
ID : 16 or does it? Pupil 2, 14:10
ID : 18 no because there is mainly unhealthy food Pupil 1, 14:59
ID : 19 the food is cooked in loads of oil. Pupil 1, 15:01:
ID : 21 mc donalds also sell a healthy variety of food Pupil 2, 15:05
ID : 22 there in salads sold by them selves or in burgers Pupil 2, 15:06
ID : 23 is there anything else healthy Pupil 2, 15:08
ID : 24 is there anything else healthy? Pupil 1, 15:10
ID : 26 there is a lot of fat and salt in the food and that is bad for your body Pupil 1, 15:13

From this print out of contributions one can be identified which matches with the sequence on the map below:
ID : 1 McDonald's is healthy food. Facilitator 09:38
ID : 18 no because there is mainly unhealthy food. Pupil 1, 14:59
ID : 19 the food is cooked in loads of oil. Pupil 1, 15:01:
ID : 21 McDonald's also sell a healthy variety of food. Pupil 2, 15:05
ID : 22 there in salads sold by them selves or in burgers. Pupil 2, 15:06
ID : 23 is there anything else healthy. Pupil 2, 15:08
ID : 24 is there anything else healthy? Pupil 1, 15:10
ID : 26 there is a lot of fat and salt in the food and that is bad for your body Pupil 1, 15:13
It is only by putting the map together with this contribution that the groups can be identified and the layout of the argument in which it engaged can be understood, see Figure 4 below.

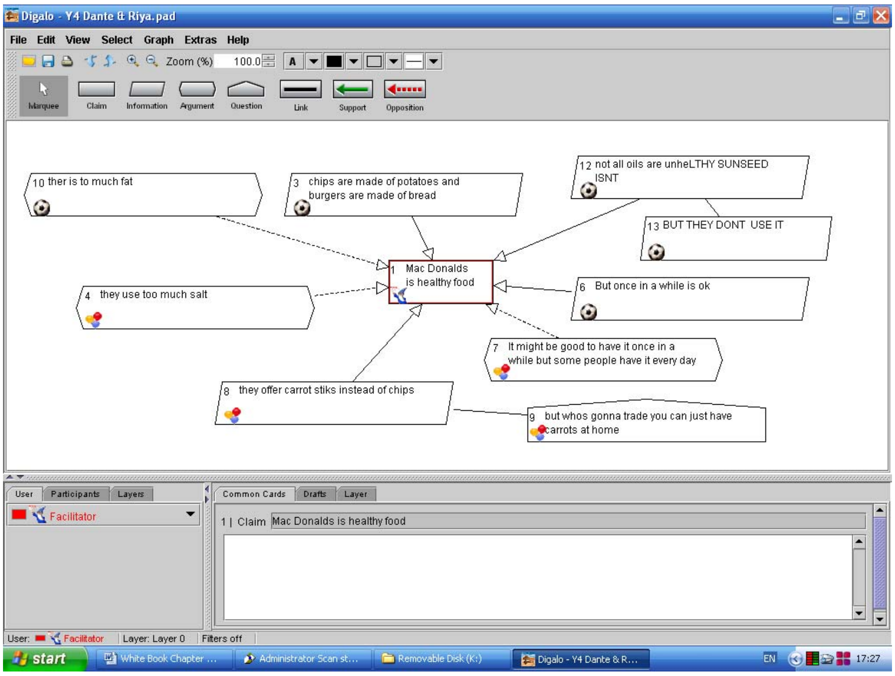
Figure 4 Year 4 McDonald's argumentative map



McDonald's activity
The groups working on the McDonald's topic had less than 30 minutes to produce their maps and the students had done no research on the topic and were given no data. However, healthy eating is a common topic in the news, is stressed frequently in UK schools, and is a specific topic in science in year 5 (9-10 years). In the map the teacher provided for all groups the initial McDonald's statement was in the top left corner. One year 4 group moved it to the middle and then worked around it. It was a purposeful and conscious decision. Children came up with good ideas but linked their arrows to this centrally placed statement, *McDonald's is healthy food*, rather than showing support or opposition to each others arguments. The children moved the initial statement to the

centre of the screen and did not support or oppose each other's arguments, instead they supported or opposed the initial statement (see Figure 5)

Figure 5. Changed McDonald's map.



All Year 4 maps were at level 2 and the arguments were somewhat dissociated from each other. They touch on fat and salt content as being bad for health and carrots and sunflower seed oil as being good for health. One map included a good rebuttal as a provocative question relevant to health and economics "but whos gonna trade [when] you can just have carrots at home", but following contributions ignored this economic argument.

Year 5 students were working nearer to level 3. A more usual digalo argument structure was adopted with support and opposition arrows linked to arguments as they occurred rather than to a central statement. The scientific language was richer e.g. references to protein in chicken. One map had the suggestion that children's meals at McDonald's are healthier than the adult equivalent. Rebuttals were all simple and some had no backing e.g. "Have you been [there] to know if the food is healthy or not?" One map included a provocative question "Do we have any proof that it is healthy?" There were more contributions relevant to the standards by which *healthy* can be judged.

In Year 6 maps the main point, health, is seized upon quickly without claims of supporting and opposing McDonald's meals. Language is less scientific but refers to *taste*, *fattening*, and *fizzy drinks* as well as *healthy* with more questions about these aspects of the topic. There were a larger number of provocative questions, for example "how much fat do you have to have in something to say it's fattening?'

In year 7 the children use words like chemicals and processed but their arguments were still simple. The teacher suggests that they lacked motivation; he had not taught this group in the past and thought that not having a rapport might have been a factor in their lack of interest. The teacher was quite disappointed with the software because of technical problems encountered. He would have had some difficulty teasing out contributions to assess any one group because he cleared the screen each time a new group started. It would have been better to have had more than one file with the same opening sentence so that the argument from each group was separate.

6.7 Case D Greenway: energy, food and diet

Evaluation of this case was through measuring student many were not saved, so the analytical framework was not used to evaluate maps.

Overview of Energy
The teacher at Greenway was teaching a typical Year 8 (12 – 13 years) scheme of work, in which each topic was divided into one-hour lessons. The teacher had three lessons per week with the class and was expected to teach the topic within the time-frame allocated. The teacher was very IT literate and was interested to develop her skills of teaching argumentation through using digalo. As an inexperienced teacher, she needed help in devising suitable activities that would be commensurate with the scheme of work in her school. The case was co-constructed by working closely with a researcher. The starting point for the case design was the scheme of work that included a focus on issues relating to renewable energy sources, in particular the environmental aspects of generating electricity from such sources.

The scheme of work included lessons on the following, with suggested teaching strategies:

- Review energy changes/ conservation (practical and group discussion)
- How does electricity transfer energy? (practical and role play)
- Building a battery (enquiry activity)
- Where do we get electricity from? (practical investigation)
- Research and debate on energy sources and the environment (presentation and **argumentation**)
- What are we paying for when we use electricity? (practical and calculations)
- How do we reduce the waste of energy? (Discussion)

In collaborative planning with the teacher, it was decided that research and debate on energy sources would be a good point at which to incorporate a digalo activity. The students were asked to work in small groups and carry out their own research into one of four renewable energy sources: hydroelectric, tidal, wind and ‘poo’ power (from animal waste). They presented the findings of this research to the whole class, and then designed fact cards, highlighting the pros and cons of their allocated energy source. Students used these fact cards to argue for the ‘best’ source of energy, using digalo.

Implementation of the case
The teacher introduced argumentation through the context of mobile phones, and through using an argument ‘should cannabis be legalised?’ as a way of modelling argument on the Interactive Whiteboard. She then provided resources for students to carry out their own research on one of the four energy sources. Students researched in friendship groups the advantages of one of hydroelectric, tidal, wind and poo power. They presented the

outcomes and made fact cards of advantages and disadvantages of their chosen energy source. After the presentations from each group of students, and the construction of the cards, the students were provided with access to a computer suite for one hour, during which time they were asked to read the fact cards and work on constructing their arguments.

The digalo lesson involved students working in twos on each of the 15 computers in the suite. The lesson began with the distribution of all the fact cards, which the teacher had reproduced so that each pair had a complete set of four cards. Their task was to use digalo to discuss which was the most environmentally friendly source of energy and why. The fact cards provided a useful source of evidence and students were able to engage quickly on the digalo task, once this had been modelled for them.

The teacher lacked experience and confidence in setting up argumentation using Digalo. A decision was made to begin with only four icons, claim evidence, argument and question, and three links – support, opposition, link. The researcher made some digalo icons out of card using energy sources that the students would not have - evidence for solar and nuclear energy sources, so that she could model an argument on the board and point out ways in which the different icons could be used.

After students had spent 15 minutes using digalo, the teacher introduced a sheet that asked students to prioritise the sources of energy. This led to further discussion and digalo entries, followed by a plenary class debate. Most digalo maps were not saved, as the save feature on digalo reverted to the original file.

Overview of Food and Diet
The starting point for the case design was the school curriculum for students aged 12 – 13 years, which had been adapted from the national curriculum for science. The curriculum included a focus on issues relating to nutrition, diet and healthy eating. The overview of this topic was:

- What happens to food inside the digestive system (discussion, penil and paper activities, enquiry activity to build a model gut)
- What do digestive enzymes do (demonstration, practical experimentation using pepsin and gelatine)
- Diet and health (research and debate)
- Respiration (demonstration and practical experimentation, reasoning)
- Heart and circulation ((pencil and paper activities)
- Structure and function of lungs (pencil and paper, enquiry activities)
- Respiration in other organisms (research and role play)

The teacher planned to begin the topic the week before the digalo activity with an investigation into the action of pepsin on gelatine, followed by graph work. The subsequent lesson would occur in the booked computer suite addressing the question of diet and health.

The students were asked to work in small groups and draw on research evidence about the advantages and disadvantages of different diets. The teacher chose to focus on diets that students would be aware of, or were ‘unusual’, such as the Atkins diet and the cabbage soup diet. The students were to consider arguments for and against different diets and their effect on health, using digalo. The main objective of the case was for students to construct reasoned arguments about different diets, using evidence gained from research. They were to use digalo software to construct arguments and to counter-argue from different positions.

Implementation of the case
The students were provided with access to a computer suite for one hour, during which time they read the research evidence and worked on constructing their arguments. The teacher began the session by introducing a context for argument using a MacDonalds hamburger and vegetable salad. She posed the question of which is the healthier option and why? She then provided a set of resource sheets to all students, posing the problem 'is this diet healthy?' and the researcher again modelled arguments using digalo icons.

Students worked in friendship groups to evaluate a particular diet, using resource sheets from the web on Atkins diet, Cabbage Soup diet. These diets were evaluated against a chart of the components of a balanced diet. Students responded to an opening question on digalo 'is the Atkins/Cabbage Soup diet healthy?' They worked in friendship pairs to construct an argument from different viewpoints. They used information from the sheets and discussed how to place their arguments on digalo maps. The teacher monitored discussions and contributions by observing students and after the digalo session asked them to review their arguments. She held a plenary discussion on the pros and cons of different diets. The students wrote up their arguments as an essay for homework.

The energy case had been more successful than the food and diet case in terms of engagement and quality of maps. The researcher and teacher concluded that students needed enough sources of evidence when engaged in argumentation. The resources from the food activity required more reading and synthesis before the session.

Evaluation discussion
This Year 8 class undertook further work with argumentation and another digalo case on Earth and space that ran beyond the period of research visits to the school. This class therefore experienced three intensive periods of the teaching of argumentation over a period of 5 months. A parallel Year 8 class was taught by the same teacher but she did not include argumentations sessions in their scheme of work, they were taught the same lessons as the other Year 8 classes in the school. The evaluation therefore included a comparison of these two Year 8 classes of their performance on an end of year test question, about evidence for heart disease, that drew on argumentation skills (see Appendix 3). Results are shown in Figure 5, the class who had experienced argumentation lessons and digalo received much higher scores on this test item than the class who had not.

Figure 5 Results for two year 8 classes for Heart disease question

Score out of 5	0	1	2	3	4	5
Number of Class A (digalo) students	0	4	9	9	3	1
Number of Class B (not digalo) students	16	9	2	0	0	0

6.8 Conclusions

Planning a lesson

A teacher's own understanding of a topic used with digalo needs to be clear. Teachers will need to have considered what science they really want students to question and understand and how argumentation will emerge from that practical experience. The questions teachers might ask students to move their argumentation on and what questions students may ask, especially during practical work, should be thought through. Teachers may also need to include in their planning time to model argument structure and content if students have not used digalo before. They will also need to think about the arguments that they want to provoke from the students and how they will prompt better arguments;
Teachers should provide:

- a stimulus for argumentation by presenting enough knowledge to get started and to motivate students to argue;
- a sequence of activities to include digalo and enable students to improve their argumentation skills, build on their initial arguments by carrying out practical activities to test their arguments and improve their scientific language e.g. set up a digalo activity to draw out initial ideas followed by classwork or practical activities and return to digalo for refinement of arguments. If a digalo activity is not integrated into a series of lessons there is often no time allowed for reflection on the content or process of argumentation.
- time for students to look at all maps at various points in the activity so that they see alternative arguments and different use of language by peers.

Using published resources without adapting them for use with Digalo activities can impose inflexibly.

Setting up Digalo

Clarity in setting digalo up is important because students will be unable to construct coherent arguments if the card options offered are ambiguous. The teacher will need to configure the toolbar so that the number of cards is appropriate to the ability and age of the students using digalo. There were issues of accessing the files to start a digalo session.

Folders must be set up so that students do not have to go through too many actions to reach the right file to open and then again when saving digalo files.

Allowing for differential learning
In the UK education system differentiation is very important and digalo was seen as a means of introducing differentiation. Even students who have difficulty reading and writing can still express an opinion, ask questions and evaluate other people's arguments. Misconceptions expressed can stimulate others to explain a concept and this helps all of the students in a group to clarify their thoughts and understanding. Students achieve differentiated outcomes in the contributions they make rather than being given differentiated texts to work with. Everyone has the same starting point with the same toolbar configuration whatever their age or ability; there is no question of segregation by working on something different.

Construction of an argument
Teachers themselves need to have a good grasp of the meaning of an argument before they can teach it. Any explanation of argument construction must be very clear to students. Teachers need to model an argument using the labels on the digalo toolbar cards so that their meaning is understood by all.

Language development
Initial digalo activities invariably showed limited scientific vocabulary. Teachers suggested that students learned their language from each other when using digalo and looking at each other's maps. Students with poor reading and writing skills may not be able to participate in the same way as their peers; they may need more support e.g. someone to type their contributions.

Social factors
There is evidence that students liked working in groups (Case A). Those who expressed themselves well could articulate arguments more clearly, those with a poorer vocabulary benefited from sharing these arguments. Poor readers may need to be paired with more able students for all pupils in a class to benefit from using digalo. Group members shared their understanding with each other. Those with practical capabilities demonstrated e.g. construction of an electrical circuit, to those with better conceptual understanding.

For co-construction of knowledge to be take place and be effective small groups (fewer than 5 students) are essential. A comparatively long waiting time to make a contribution allows students to become distracted. Grouping in a particular way should be a strategic decision for the teacher and not a haphazard consequence of student choice.

Mediation
Teachers are more likely to stimulate students to think for themselves by asking open questions; students then reason their way through the questions put to them. When using digalo the pupils must also be encouraged to ask each other open questions and draw out knowledge, clarification of meaning and explanations. A digalo activity may work well socially but one teacher noted that those who benefited least were the children who typed all the contributions and remained on the periphery of interactions. Asking more open questions allowed teachers to encourage thought rather than telling answers. Teachers were responding to students' ideas and questions rather than following a completely set agenda.

Assessment

Digalo maps give an insight into students' understanding of the problem set, the subject content and how they constructed arguments. However, the collaboration in the whole activity is not captured in the maps. Some other way e.g. video may be needed for a full assessment process. The teacher must consider what the assessment is showing; digalo contributions capture exchanges which would otherwise be ephemeral. Students may also ask questions which stimulate an argument to which they make no other contribution. How to assess Digalo interactions and contributions is an area that needs further research.

Dissemination to other teachers

Teachers will need to change their colleagues' attitudes to time limits on and subject content of lessons. They will need to emphasise justification of ideas and sharing thoughts.

The teachers may change their pedagogy to use digalo but the barrier of lack of technical expertise remains even though students are likely to be technically adept. Teachers appreciated the current use of digalo but noted that it offered a huge number of options with which to make science lessons better. Integrating its use with whiteboard software would be particularly helpful. It was also noted that those teachers with only average ICT skills can carry out a digalo activity with children but need more help with planning lessons and more CPD to help them to use it regularly in the classroom. There was no time in this project for using the advanced features offered by digalo software. The teachers involved in the project in the UK saw the benefits of using digalo for literacy because students were creating arguments and using persuasive language. It could also be relevant to social science, history, geography, citizenship and PSHE (Personal, social and health education).

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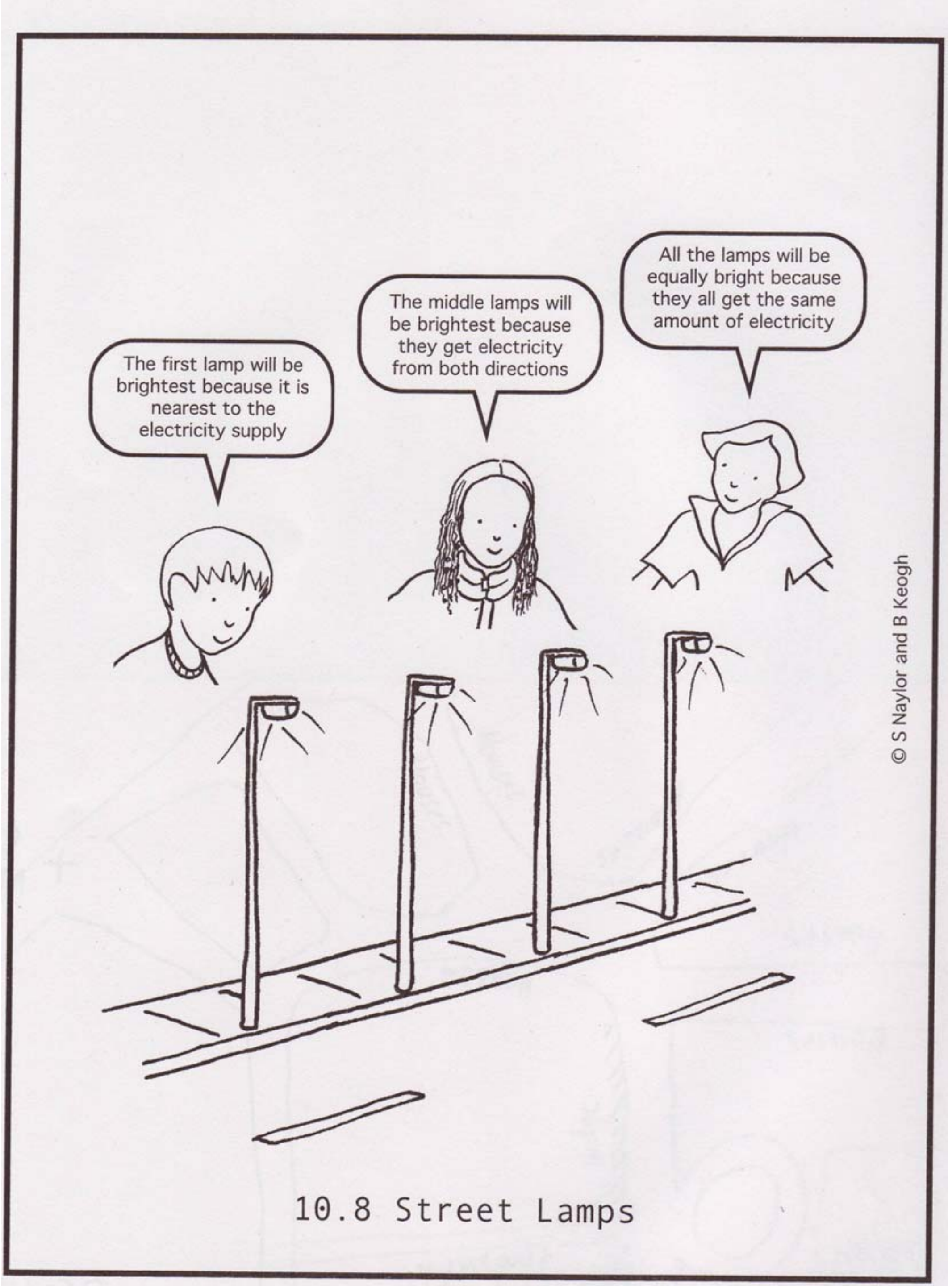
Appendix 1

Concept cartoons used at Case A Kingsland

10.5 Longer Wires


The first lamp will be brightest because it is nearest to the electricity supply
The middle lamps will be brightest because they get electricity from both directions
All the lamps will be equally bright because they all get the same amount of electricity
© S Naylor and B Keogh
10.8 Street Lamps

Appendix 2 Questionnaire for Case A

Name of School **Country** **DATE**	
Name	**Age**

Topic title

1. Circle the number of lessons in which you used Digalo

1 2 3 4 5 more than 5

2. How happy were you to work with Digalo? *Circle a face*

I didn't like working with Digalo at all ☹

It was OK 😐

I really enjoyed working with Digalo ☺

3. Circle a face for each sentence to say what you did and didn't like in Digalo lessons.

☹ I didn't like it 😐 It was OK ☺ I liked it

Using computers in science lessons	☹	😐	☺
Using pen and paper in science lessons	☹	😐	☺
Group work	☹	😐	☺
Having to think of my own ideas	☹	😐	☺
Having to argue with others	☹	😐	☺
Saying what I think	☹	😐	☺
Writing what I think	☹	😐	☺

4.Did you learn anything <u>new</u> about the topic? YES/NO

Say what new things you learned

5. Did Digalo help your group to work together?
YES/NO

If YES then how did it help or if NO why didn't it help?

6. Circle the face for each sentence to show how you worked with Digalo.

☹ **No** 😐 **sometimes** ☺ **Yes**

Digalo made me:

More interested in the topic ☹ 😐 ☺

Read about the topic ☹ 😐 ☺

Think about the really important points in the argument ☹ 😐 ☺

Weigh up evidence ☹ 😐 ☺

Learn facts ☹ 😐 ☺

Discuss the topic ☹ 😐 ☺

Develop my own ideas ☹ 😐 ☺

Think about my next argument when I had made a point ☹ 😐 ☺

Think about other people's points ☹ 😐 ☺

Understand what an argument is ☹ 😐 ☺

7. Why do you think you need to argue about topics in science?

Appendix 3 Test item from Case D

Read the magazine cutting about research into heart disease.

More heart disease in older women.

Heart disease amongst British women in the 60-79 age group is more common than previous research suggested. A recent study of 4,286 British women in that age group indicated that one in five showed signs of heart disease.

(a) Why can the results of this research **not** be used to draw any conclusions about heart disease amongst women across the world?

....

....

1 mark

(b) Give **one** reason why the data collected in this study is likely to be reliable.

....

....

1 mark

(c) After reading the magazine cutting, pupils wrote the ideas below.

Decide if each idea is supported by information in the cutting. Tick the correct box.

Use the information in the cutting as evidence to justify your decision in the third column.

Idea	Is the idea supported by evidence?	Use the information in the magazine cutting as evidence

	Tick the correct box.	**to justify your decision**
One in five of all British females show signs of heart disease.	Yes ☐ No ☐	
Earlier treatment for heart disease must have been more effective than modern medicines.	Yes ☐ No ☐	
Four out of five British women in the 60-79 age group showed no signs of heart disease.	Yes ☐ No ☐	

3 marks

maximum 5 marks

ESCALATE: The White Book

Chapter 7: Description of the experimentations in Greece

Sub-chapter 7a: The implementation at the National Kapodistrian University of Athens

C. Kynigos, F. Moustaki, K. Makri and A. Antoniou

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7a.1. Background on the national and institutional context

In central European countries, and particularly in Greece, there is a strong element of revelation (of knowledge, or of the truth) engrained in the curriculum (Kontogiannopoulou & Polidorides, 1996), part of the cultural heritage of the past century. In the classical sense, curriculum is perceived as a centrally conceived, developed and mediated body of knowledge to be delivered by the teachers. Cultural, political and social issues are central to decisions on curriculum content and mechanisms for curricular change (some particular policies for instance have been influenced by broad educational performance studies such as TIMMS, OECD/PISA, Kynigos, 2003). In their everyday professional life, teachers are obligated to follow the linear, sequential steps of a formal curriculum, static with little or no control on the choice of learning content and activities. Pre-prescribed curricula are "handed" to them as static, unchangeable documents with a generic character and emphasis towards descriptive language and vague pedagogical terms.
At the systemic level, the role apparently prescribed for teachers is that of content delivery. In practice, there are of course many teachers who actively reflect and reformulate their practice, who try out innovations, which are by definition sensitive to the context of the classroom and their students. However, they are not encouraged to do so by the systemic and organisational context and often feel that this is an uphill struggle, which no one recognises or values besides the students themselves. The system prescribes a busy ant-like existence for the teacher' s day to day job, not leaving much space for concentrated planning or reflection.

In the context of educational technology integration in particular, as a consequence of the revelatory paradigm, the majority of instructional materials are designed by experts who are not teachers themselves. These products are either depreciated by teachers, or don't end up in being used in classrooms, as they do not integrate characteristics and potential which are considered as important from this particular professional community. In fact, their design rationales often remain implicit and the material is conceived as a finished product, not suitable for negotiation or redefinition by teachers, whose role is restricted to that of the "implementer".

It is common sense that in such conditions, the way new technologies are portrayed by the system to the teacher community and the way in which inevitably this community tends to perceive the technology, are as a new means to optimise the "pipeline" metaphor for education and the "ant-like" professional mindset of teachers.

Furthermore, in the Greek educational context, designing learning activities with technology is not a part of a teacher's official agenda, as the centralised educational system neither dictates this as a systemic prerequisite, nor acknowledges it as a professional strength (Kynigos, 2007). It may be the case that this would make it much more difficult for a teacher working in this system (rather than within an Anglo-Saxon one) to understand, adopt and value innovation where students are encouraged to generate their own meanings through personal expression, experiment and constructions (Kynigos & Argyris, 2004).

With the advent of digital media and the challenge of inventing ways of using them in education, new definitive aspects of learning environments, never previously taken into account, emerged. These relate to the social orchestration and grouping of students, the ergonomics of the learning space and resource allocation, the aims of use of the digital tools, etc. However, activity plans for technology enhanced learning environments have to date been highly influenced by traditional lesson plans and the institutional, social and educational assumptions therein. According to Dimitrakopoulou (1988), most of these activity plans are teacher centred, as they depict a didactical, rather than a learning sequence, focusing on the actions or steps of the teacher, in the form of teaching guidelines and ignoring the actions of the students or groups of students.

Digital and communicational media, however, invite both pedagogical knowledge and thinking 'out of the box' with respect to new kinds of learning activity, new means for expression[3], new kinds of social structures, new temporal and spatial conditions for learning. This has been hardly taken into account in the education and research world and many technology solutions and uses are designed with non-technology environments in mind.

There have been, of course, important reactions to the traditional instructional design rationale. Some of them (Duffy & Jonassen, 1992; Derry & Lesgold, 1996) have shifted the focus on the context of the learning situation, presupposing that learning can't be considered as detached from the surrounding environment where it takes place (situated cognition). Others, such as Wenger's "community of practice" approach (Wenger, 1998), have stressed the importance of the identity –sense of belonging-, of learners as members of purposefully shaped special interest groups with a "joint enterprise" and common focus and the meanings created within such communities.

During a collaborative activity, a community works towards a common goal, which can be an ideal object to be created, or a specific improvable object (Bereiter et. al., 1994). This object is both the centre of the activity, and also functions as a communicational tool to shape a common language within the community. Cobb et. al. (2003) extend this notion by proposing the term "boundary objects", e.g. specific objects within different communities, which are «*relatively transparent means of conveying meaning among the members of the community who created them*». They can also be the centre around which community members organize their activities and can additionally operate as tools for communication among the members of the same community, and the members of other communities.

For the purposes of the experimentation in Athens, we used cases, -otherwise called activity plans or 'scenarios', as the objects of negotiation –and the centre of activity-within our community. These have primarily been designed in the Educational Technology Lab as research instruments for on-site action research in schools, as

[3] for a further elaboration on the term "expressive media", refer to Kynigos , 1998, Kynigos, 2005, in press)

functional specifications for the development of specialized innovative educational software solutions and as material for teachers and students engaged in the activities. They have gained the status of best-practice descriptions of ICT use through many hours of implementation in schools. The style of writing scenarios has been widely adopted in Greece in projects funded by the Ministry of Education and in the Ministry's teacher portal where many of these are being uploaded. The 'scenarios' developed by E.T.L. have all focused on integrating educational and technology innovation aimed at best-practice use of technology for learning. They have addressed a breadth of ages (7-15) and domains (Mathematics, History, Language, Geography, Informatics, Science) and are based on an interdisciplinary thematic based perspective involving collaborative project work.

Though there are plenty of references in the various uses of activity planning in the literature, the emphasis is put on their use as research tools, useful for clarifying specific research questions (Doerr, 1996; Jackson et al., 1996; Harrison & Treagust, 1998). We adopt an approach favouring the inclusion of activity planning in teacher training programs, the latter functioning both as boundary objects for community formation and as tools for professional reflection. This is line with what Jaworski (2003, 2004) and Wells (1999) have termed as the "inquiry approach to curriculum design". According to this, education has a dialogic character: procedures, programs and curricula are constantly revised, as objects for negotiation. The teacher is therefore considered as a reflective practitioner who shapes professional practice through critical reflection (Shön, 1985; Eisner, 1998) and as an active creator of his/her personal pedagogy, directly involved in planning and implementing innovation (Hoyles, 1992; Kynigos, 2003; Kynigos et Argyris, 2004; Kynigos, in press).

7a.2. Description of the social context of the implementation

Approaching the teachers – forming the Greek "ESCALATE Community"

On the basis of the above theoretical principles, activity planning has been embedded as a fundamental element in teacher education programs previously implemented by ETL (Kynigos, 2003). It is also an integral part of the syllabus of the post graduate course "Pedagogy of Specialised Subjects with ICT": http://etl.ppp.uoa.gr/_content/Didaktiko_ergo/index_tutorial_en.htm.

This course is interdisciplinary and addressed to teachers from both theoretical and technical specialties. Its syllabus includes various activities designed to introduce teachers to notions of inquiry learning, argumentation and collaborative work. The teachers, throughout several modules, work with expressive media (e.g. microworlds), design activity plans in collaboration with peers, present them, discuss and revise them. They also use digital tools for communication and collaboration (fora, blogs, etc). Having completed the course, the students already form a pool of professionals, characterized by increased sensitivity and awareness with regard to issues of technology and its pedagogical integration.

This year, the enrolled teachers attending the course are 17. Seven of them are working at the same time as in-service practitioners while the rest of them are pre-service teachers with limited teaching experience. Although their main specialization is on science and technology education, the predominant characteristic of the group's composition is the members' diversity of expertise (mathematics, engineering and technology, informatics, sociology, pedagogy and psychology), their institutional distribution and their common interest in pedagogical issues related to the integration of digital media in their teaching practices.

Three months before completing the taught course modules, we asked the teachers if they would like to participate in the ESCALATE project experimentations. The activities in which they would be engaged during the experimentation process were consistent with their former practices in the post graduate course and also relevant to the module "Digital Media and School Practice", which they were attending at the time. However, the teachers didn't view the suggested activities as a routine task that they had to carry out or as an obligation that they had to accept and fulfill. Their particular interest both in the design and development of activity plans and in the exploration of ways in which the use of digital media could be integrated in their classrooms, motivated the teachers who seemed to be highly challenged by the prospect of designing activities that would incorporate the use of argumentative and inquiry-based computational environments.

As it was eventually formed, the Greek ESCALATE community consisted of 3 researchers and 17 teachers, post graduate students of the "Pedagogy of Specialised Subjects with ICT" course. Two of the researchers were science specialists and experienced teacher educators while the other one was a technology teacher and at the same time a post graduate student of a course in ICT and pedagogy.

7a.3. Description of the task

General idea

For the past 15 years, ETL has been engaged in several innovative activities such as the development of educational activity plans -aimed to be used as instruments for on-site research in the school environment or as open-ended material for teachers and students- and the design and implementation of innovative teacher education methods. On that ground, we decided for the implementation of the ESCALATE cases, not to work with school students but with teachers who attended a post graduate course in ICT and Pedagogy.

The main idea was to place those teachers in the role of the ESCALATE *"case designers"* and study the ways in which they would use the Microworlds and the Digalo in the process of developing their activity plans. Working together, the teachers would prepare activity plans on the basis of one of the ESCALATE Microworlds and use Digalo and asynchronous tools in order to communicate and argue on specific elements of the designed plans. This course of action would give them the opportunity to test and evaluate the proposed tools –both the Microworlds and the Digalo- by themselves and discuss on the possible pedagogical value the integration of such tools would bring to science learning and teaching in their classrooms.

Task phases

Initially, we asked the teachers to form workgroups consisting of two or three persons. We encouraged them to include in their workgroups persons with different expertises (e.g two mathematicians could invite in their workgroup a sociology teacher) so as to evoke the generation of holistic approaches to the emerging pedagogical issues. Working collaboratively for more than a week, the members of each workgroup were expected to develop an activity plan that would incorporate the use of one of the three ESCALATE Microworlds (i.e "The Hit the Balloon", "The Mysterious Forces" or "The Juggler") and the use of the Digalo environment. Since we didn't want to impose our choices, we asked the teachers to distribute the Microworlds over the workgroups by themselves, but make sure that there would be at least two workgroups for each one of the three Microworlds. The communication mode among the members of the workgroup would be of their own choice.

After developing their activity plans, the workgroups that have chosen the same Microworld would exchange their files and use the Digalo platform to discuss the structure and the content of each activity plan, compare the ways in which enquiry and argumentative learning activities were integrated in the plans and make remarks about the possible implementation of the developed plans in real classroom settings. During or at the end of this phase, the teachers would have the opportunity to revise their plans and make correction if they consider it necessary.

Finally, during the third phase of the experimentations, the teachers would make public to the whole "ESCALATE Community" their activity plans and discuss using asynchronous communication tools (forums) or during face to face meetings the prospect of integrating the use of the Microworlds and the Digalo environment in their pedagogical agenda. The inquiry and argumentative activities each workgroup has envisaged to implement in its own activity plan would be also a topic of conversation for the "ESCALATE Community" during the plenary sessions at the Educational Technology Lab or through the Community's forums.

Briefly, the teachers would:

- use the Microworlds as a basis to develop activity plans, through which specific didactical goals would be addressed
- use Digalo for the discussion between the groups which would work on the same Microworld. Through this they would assess and distinguish good practices concerning the further use of Digalo in the classroom with their pupils.
- discuss, in face to face meetings and using asynchronous communication tools, on the ways in which Digalo and the developed Microworlds could be used in classrooms.

Main choices regarding the role of technology in the task design

The task of developing an activity plan was presented to the teachers as an "ill-structured problem". There were no work sheets or any other directive on how to design their cases. In the language of rhetoric and communication, "ill structured problems" are defined by Flower et.al. (1989) as rhetorical situations, in which the subject has no clear instructions on how to proceed to a solution. In contrast to "well structured problems" (e.g. games) where there exist written, coherent rules, there are no readymade solutions for writing problems. The whole composition venture aimed at operating as a mechanism for reflection and self-evaluation.

In addition to the wording of the writing tasks, deliberately non-directive and open-ended, the role of technology was also left implicit. A basic premise of the technology use rationale was that teachers don't learn effectively if they adopt the "manual style" of learning a piece of technology, making the technology itself the object of study and rote learning the functionalities of the tool. It is much more effective for teachers to learn in a contextualized, theme-based style, where technical know-how comes gradually as the need arises from the problem situation at hand (Kynigos, 2003). Whenever teachers were found to participate in a design including facing a "problematic situation", where the role of technology was not predefined, the problem did not "solve itself" by pushing a button or proof reading a manual, but through discussion and experimentation with the technological tool (Kanstrup, 2003). During the process of involvement with the problem, several methods, models and theories are tested before a proposed solution is reached. This form of problem solving could be better conceptualized through the metaphor of "bricolage" (Lévi-Strauss, 1969: 28-33), used to depict this rational for the craftsman (Harper, 1987) and technician (Orr, 1996) professions. Kanstrup (2003) proposes the exploitation of this idea within the teaching profession, claiming that this view is not far from that Schön's "reflective practitioner". Teachers' work with technology is, according to this view, considered as a "reflective dialogue with materials" or, "bricolage".

Main choices regarding the researcher's role during the tasks

The researchers would monitor the Digalo synchronous sessions without intervening in the e-discussions, provide technical support whenever needed and participate in the asynchronous discussions. They would also decide on the agenda of each face to face meeting and keep field notes during the meetings.

7a.4. Description of the technological artefacts used

Distance learning platform

The participants of the community all had e-mail accounts and access to a distance learning platform officially used by the University of Athens (http://eclass.uoa.gr). In order to facilitate the communication among the teachers and the diffusion of the created artefacts (e.g the activity plans designed by the teachers), a special learning space, restricted to the members of the "ESCALATE Community" (code name: PPP132) was developed on the basis of the e-class learning platform (Appendix II).

The utilities integrated in the "ESCALATE Community" learning space were carefully selected so as to suit the purposes of the experimentation process. Divided in five distinct sections, the learning space mainly served as a venue for the communication among the members of the ESCALATE Community. The five sections visible and accessible by all the Community members on the learning space were:

- A "Links" section: This section provided a list of links related to the ESCALATE scientific basis and problematique.
- An "Announcements" section: The announcement section was used for the researchers–teachers every day communication (e.g announcements regarding the date and time of the forthcoming meetings)
- A "Forum" section: Two sets of forums were created.
  The first set included three different directories, one for each of the ESCALATE cases (i.e "The Hit the Balloon", "The Mysterious Forces" and "The Juggler"). Each one of those directories contained several sub-directories that hosted the community's conversations on the activity plans developed by the teachers. For each of the activity plans, there was a specialized directory in which the teachers could post their messages regarding the specific activity plan and expect a reply by the authors of the plan.
  The second set of forums comprised three different directories as well. Those three directories corresponded to the technological artefacts used by the ESCALATE Community for the design and the development of the implemented cases (i.e the MachineLab, the E-Slate and the Digalo).
- A "File Sharing" section: The teachers used this section in order to make public and share their documents with the rest of the Community members.
- A "Documents" section: The directories created in this section contained the Microworlds, documentation on the technological artefacts used and the activity plans developed by the teachers.

Escalate Project Technological artefacts

For the development of their activity plans, the teachers used, in different levels, both the inquiry and argumentation-based computational environments (i.e the Microworlds and the Digalo) that the ESCALATE project partners had used for the design of the project's cases.

Inquiry- based artefacts

The teachers had in their disposition three of the Microworlds developed during the ESCALATE project: the "Hit the Balloon", the "Mysterious Forces" and "The Juggler". The tools that were used for the authoring of those Microworlds (i.e the E-Slate and the MachineLab) were also available through the ESCALATE (http://escalate.org.il) and the Educational Technology Lab (http://etl.ppp.uoa.gr/_content/download/index_download_en.htm) web-pages.

Since the microworlds can not be perceived as an end product, but as a building kit (Kynigos, 2004), the three microworlds presented to the teachers so as to be used as a basis for the development of their plans, could be customized and used in ways that could be distinctly different than the ways we had thought of using them as we designed the project cases. The teachers had the opportunity to concentrate on certain functionalities of the microworld (i.e the dynamic manipulation or symbolic Logo script) and propose activities that could integrate the use of those specific elements of the microworld.

Descriptions of the microworlds developed and their authoring platforms are provided in Chapter 2 and 3.

Argumentation -based artefacts
The Digalo environment was made available through a Digalo server (http://zeno8.ais.fraunhofer.de/digalo/). The teachers ran the Digalo mostly in synchronous session mode as they worked in together with other Digalo users (members of the same or different workgroups) on the maps we had initially created for them (i.e ETL_Ballon_1, ETL_Juggler_2 and ETL_Mysterious Forces_1). They could also use Digalo in single session mode as we had installed the environment in the Educational Technology Lab's PCs.

Documentation
Apart from the technological artefacts themselves, we also provided the appropriate documentation so as to support the teachers in the use of the E-Slate, the MachineLab and the Digalo platform. Scripting in logo-based environments manuals for those who wished to deepen their knowledge in this domain and manuals for the installation and the use of Digalo were available through the "ESCALATE Community" learning space. Documentation describing the pedagogical rationale underpinning the use of such tools (inquiry and argumentative) and information regarding the vision and objectives of the ESCALATE project were also made available to the teachers.

7a.5. The description of the course of the activities themselves

Communication among the members of the community
The course of the activities was based on a blended training model combining face to face meetings, asynchronous and synchronous web-based communication. The asynchronous communication was conducted through the "ESCALATE Community" forums, in the learning space provided by the e-class platform and through e-mail exchange. Synchronous (chat-like) communication also took place as the participants worked in the Digalo environment.

The face to face meetings took place at the Educational Technology Lab, at the National and Kapodistrian University of Athens. The lab is equipped with projection devices and 10 workstations, all having access to the Internet. In each of those work stations we had installed the technological artefacts the teachers would use for the development and the discussion of their activity plans. The interior of the lab is suitably arranged so as to allow individual and small group work on the stations, as well as group activities around a table.

Course of Activities

<u>*First meeting*</u>

The first meeting took place on November 9th, 2006, under a three-fold agenda:

a) theoretical introduction,
b) presentation of the technological artifacts to be used and
c) group formation and sharing of workload.

After a concise introduction to the basic notions and theoretical issues of the ESCALATE project -such as a definition of enquiry and argumentative learning, Toulmin's argument pattern and the concepts of CSCW and CSCL, participants had the opportunity to experience three interactive demos of the respective three Microworlds developed during the course of the project: the "Hit the Balloon", the "Mysterious Forces" and the "Juggler", followed by a first discussion on the Microworlds' underlying pedagogical ideas. Finally, they were shown a demo of the Digalo tool. All these tools and their support material were uploaded on the "Documents" area of "ESCALATE Community" learning space.

The closing discussion related to the issue of social orchestration of the activity. A first idea was to divide the group of teachers in three sub-groups with similar specialties, dealing with each respective Microworld, and designing a case for using it in actual classroom settings. This idea remained an open perspective until the next meeting.

<u>*Second meeting*</u>

The second meeting took place on December 5th, 2006. By this time all members of the community had more or less experimented with the tools (i.e the three Microworlds and the Digalo), discussed on the three Microworlds and shaped their preferences and comments. Thus, the agenda of the meeting focused on final group formation and a more thorough presentation and discussion of the available software tools.

One three-member and seven two-member workgroups were formed. Three (6 individuals) were going to work with the "Hit the Balloon" Microworld, three (7 individuals) with "The Juggler", and two (4 individuals) with the "Mysterious Forces". The respective products of the groups, presented as cases, were going to be negotiated at several phases during their production, both among the workgroups who shared the same Microworld, using Digalo, and among all the members of the Community, using the learning space's forums. Having agreed on this grouping pattern, the teachers had the chance to engage in a thorough examination on how the Microworlds were designed and developed, allowing for insights with regards to their pedagogical value. Finally, they tested Digalo's functionalities as we had created three "test" pads, one for each Microworld.

The teachers agreed to develop their plans in a week, send them by e-mail to the workgroups that shared the same microworld and start discussing, using the Digalo environment, their main choices regarding:

- the ways in which they integrated inquiry and argumentative activities in their activity plans,
- the didactical goals addressed,
- the social orchestration of class,
- the consistency of the science activities to the Greek Science curriculum and
- the innovative character and added value of their activity plans.

The Microworld pads saved on the Digalo server are presented in the Appendix I.

Third meeting

On December 15th, the day of the third meeting, after a week of testing Digalo in synchronous and asynchronous mode, all teachers had experiences to share and talk about. The workgroups that shared the same Microworld had discussed on each activity plan using the Digalo tool. Some of the workgroups took into consideration the remarks made by the rest of the workgroups and revised elements of their activity plans.

The three pads, as they were shaped up to that point, were presented and commented upon. Several "use stories" revealed the teachers' practical preoccupations for the use of Digalo. The members the workgroups raised questions concerning the way in which other workgroups used the Digalo's functionalities and made remarks about the nature of the notation system the Digalo environment proposes. Being unsure about "the right way" of using the Digalo tool, the teachers asked us to provide instructions that would make explicit the kind of shapes they should use for their statements on the pad.

Apart from the Digalo pads, two of the developed activity plans, in their initial form, were also presented. The teachers discussed the way in which the authors combined in their plans inquiry-based activities and argumentative discourse activities and made comparisons between the plans presented. A theoretical debate related to the differences between applying argumentative learning in science and mathematics versus the application of these techniques in theoretical disciplines, such as languages, history and philosophy emerged as the teachers discussed on the activities they had encompassed in their activity plans.

Finally, the teachers and the researchers agreed to upload and make public to the whole ESCALATE Community their activity plans and continue their discussions through the forums of the e-class platform. During the following weeks the members of the Greek ESCALATE Community:

- commented on the developed activity plans,
- replied questions regarding the rationale of their activity plans and the didactical goals addressed,
- made suggestions concerning possible extensions of the activity plans,
- expressed their opinion about the functionalities of the tools the use of which they integrated in their plans,

- raised questions regarding the functionalities of the tools as they used them during the experimentation process.

7a.6. Iterative processes that possibly led to redesign of previous activities/ cases/ scenarios

During the course of the experimentation, the researchers' group had to rethink and reconsider issues related to practical aspects of the experimentation process.

The first issue had to do with the grouping of the teachers. Before the second meeting, the teachers had reproduced grouping techniques they had successfully employed in the past, based on their tendency to choose the partners of their groups according to their specialisation. For instance, the computer scientist paired with the technology teacher, the mathematicians formed one group and the language teacher paired with the psychologist. As the focus of the experimentation was on argumentation and inquiry, and not on disciplinary specifics, we decided to try a different social orchestration, based on the synthesis of different specialisations. This seemed to cause discomfort, as most teachers believed that they could not collaboratively design a case with colleagues of different specialisations. However, the course of events showed that not only this was possible, but also helped the participants broaden their perspective on how a tool such as Digalo could be used in different disciplines, and for different reasons.

A second issue related to the use of Digalo. After the second meeting on December 5th, we decided to:

- Initially, play the role of the *Moderator* and prepare three map interfaces (insert the names of the participants for each map and make the necessary configurations).
- Impose a *floor control* policy. Each participant should request the floor control in order to become active and use the shared workspace. That would mean that the teachers would have to take turns so as to make their contributions.
- Not to intervene as *facilitators* in the e-discussion and the *turn taking* to be automatically determined by the order of the incoming requests.
- Use the *default notation system* regarding the "Shapes" and the "Links.
- Not to define a *time frame*. The teachers could work with Digalo in a synchronous session and thus access the map simultaneously or not.
- Give all the teachers the exact *same privileges* in the workspace.
- Explain the basic functionalities but *not guide the teachers* on how they might use the Digalo tool (e.g if they would use or not different *layers* for their e-discussion). Teachers could *appropriate* the Digalo tool in fundamentally different ways, which could lead to different interactions and diagrams. For example, one might think of many different ways of exploiting a feature such as the *"grid"*.

- Not to give any distinct rules regarding the *spatial arrangement* of the statements/utterances or the way they should be organized (use the comment window so as to make a statement or the title box).

7a.7. Main observations– Studying the use of the technological artefacts at different levels

The use of the technological artefacts could be view through three distinct dimensions:

a) the experimentation with the functionalities of the three Microworlds,
b) the use of Digalo to foster synchronous argumentative discourse on the activity plans and
c) the use of the forums and other means of asynchronous communication.

The use of the three Microworlds

The three Microworlds didn't seem to trouble the workgroups. The teachers were acquainted with their functionalities and design rationale, which was expected, as the particular audience had experience on a range of logo-like environments. The authoring of microworlds and the development of corresponding activity plans were activities in which the teachers had been engaged again in the past in the context of the post-graduate course they were attending. Since they were familiar with both E-Slate and MachineLab, some of the teachers tried authoring their own materials for their students, using the logo scripting.

The use of the Digalo

However, carefully studying the maps produced by the workgroups who share dthe same microworld, the discussions at the learning space's forum and the field note we kept during the face to face meetings, the use of Digalo raised a number of issues, outlined below:

a) <u>the issue of space for organising argumentation</u>

Some workgroups chose not to use the *Title* field for their contributions. Instead, they used the *Comment* field to give a more detailed account of their statement and placed a short sentence in the *Title* field, so as to give a hint. Other workgroups initially used the *Title* field and continued to the *Comment* field when they realized that their contribution was too large. One workgroup, in order to avoid taking up much room in the workspace and create a complex diagram, used the *Comment* field several times and then used the title box to notify the rest of the workgroups. The existence of utterances both inside the shape and in the comment area turned out to be rather confusing, since the workgroups felt obliged to answer to both. That triggered a new process during which each workgroup put forward 2 contributions. One relating to the main idea and one relating to the comment. The sequence of the conversation becomes unnecessarily complex – floor control owner - time issues.

These different ways of perceiving the use of the tool, coupled with the fact that there were no explicit instructions on which shapes to use and in what way, triggered a vivid discussion on the "right" way of using Digalo, seeking for distinct rules to organize the statements / utterances.

b) *__the communicational style__*

Participants perceived the argumentative map as a tool for formal communication. There were no contributions irrelevant to the issue under discussion, such as social messages or chatting (often an element of asynchronous communication environments).

Furthermore, no technical support issues or issues concerning the Digalo functionalities were posted in the map, though they were posed to the research team, and negotiated through the forum.

Most students reported that during their e-discussion they had an oral discussion as well (on the phone), or communicated by other means (e-mail, MSN) in order to solve technical problems (i.e floor control release) or to ask for help on the Digalo functions.

c) *__the choice of argumentative component__*

One of the groups stated the question: "Which component to use if someone gives out *Information* and an the same time he has an *Idea*?", which shows a conceptual, rather than technical preoccupation.

d) *__the spatial arrangement of the argumentative components__*

Two of the maps (the Juggler's and the Mysterious Forces') don't indicate a specific spatial grouping principle, giving a chaotic impression to an outside judge. It actually seemed as if the argumentative representation wasn't arranged into a structured whole but led to a broader discussion. The third map (the "Hit the Ballon" Pad) seemed to be constructed around a leading contribution/utterance. A proposal formulated by a student was used as the starting point for the discussion.

Students reported that they spent some time organizing their discussion on the board (moving contributions, adding links, etc). Since no specific structure was offered in advance, the students had to take the initiative to come to some kind of arrangement that helped them to represent their argumentation. This could indicate that they perceived the activity of making sense of a discussion as important as expressing one's ideas into words.

e) *__the argumentation per se__*

With regards to the process of argumentation per se, in some parts of the maps it seems like the participants didn't reason systematically about an issue (idea/action/theory).

The implementation of the Microworlds in actual classroom settings is considered to be a problem that has no unique answer or acceptable solution. However, in some parts of the maps it seems that the participants didn't negotiate different or even conflicting perspectives concerning the implementation of the Microworlds (explain ideas, provide evidence, arguments, justifications, discuss alternative- opposing ideas). Instead, they stated their opinion without giving the opportunity to the others to make judgements or evaluations over this statement. The lack of negotiation could be due to the fact that the implementation of the Microworld was not considered as a highly controversial subject. The fact that the teachers had already formed a community the members of which share – more or less- the same beliefs and values concerning the use of expressive media such as Microworlds, is a noteworthy factor.

7a.8. Evaluation of the use of technological artefacts

At the end of the experimentations, we conducted two focus group discussions, one with the research team, and one with the participants.

By that time, the participants seemed more at ease with the notions of argumentation and inquiry learning, and raised several pedagogical preoccupations, regardless of their area of expertise. These were worded as open questions and can be summarised in the points below:

- Can argumentative maps foster the co-construction of knowledge among the members of a certain workgroup of students?
- Can Digalo foster collaborative learning through argumentation? Is the collaboration among the workgroups feasible through the use of Digalo? Could other tools (computational or not) foster collaborative activities? In what ways does are they different?
- Does the implementation of Digalo in a classroom guarantee the occurrence of argumentative discourse?
- What other aspects of the learning environment should be taken under consideration when designing the implementation of Digalo in a classroom (type of task, prior knowledge and skills of the students, class orchestration other resources and tools)?
- Are there any differences in fostering argumentative learning -supported by a tool such as Digalo- in science or mathematics and in theoretical disciplines (history, languages)?
- Is the use of shapes representing argumentative functions and arrows connecting utterances beneficial? How do they effect the knowledge sharing? How do the symbolic interactions within the Digalo environment relate to the learning process and outcomes?
- Why should the synchronous mapping discussions be preferable to asynchronous mapping discussions or even to face – to – face discussions? Is turn taking beneficial – floor control (synchronous – asynchronous session)
- Does the existence of shapes and arrows facilitate the acquisition of argumentative skills?
- What is more important and worth being analyzed? The content of a discussion or the process of the discussion (the actions of the participants- the existence of a meaningful sequence)?
- Should the teacher participate in a Digalo discussion/scaffold the activity? When and how? Using what kind of techniques?

- Should the teacher appoint students to different roles and ask them participate in the discussion from this specific role?
- When students should come to a consensus/decision or provide a conclusion? In the workspace of the Digalo tool? After a face – to – face interaction?

7a.9. Dissemination

The products of the Greek ESCALATE Community (seven activity plans designed by the Community's teachers and three Digalo pads created as the members of the Community argued on the plans developed) are available to the wider academic community of the University of Athens, through the e-class distance learning platform (http://eclass.uoa.gr), using the password and username "escalate" and through the Digalo server (http://zeno8.ais.fraunhofer.de/digalo/), opening the pads ETL_Balloon_1, ETL_Mystirious Forces_1 and ETL_Juggler_2.

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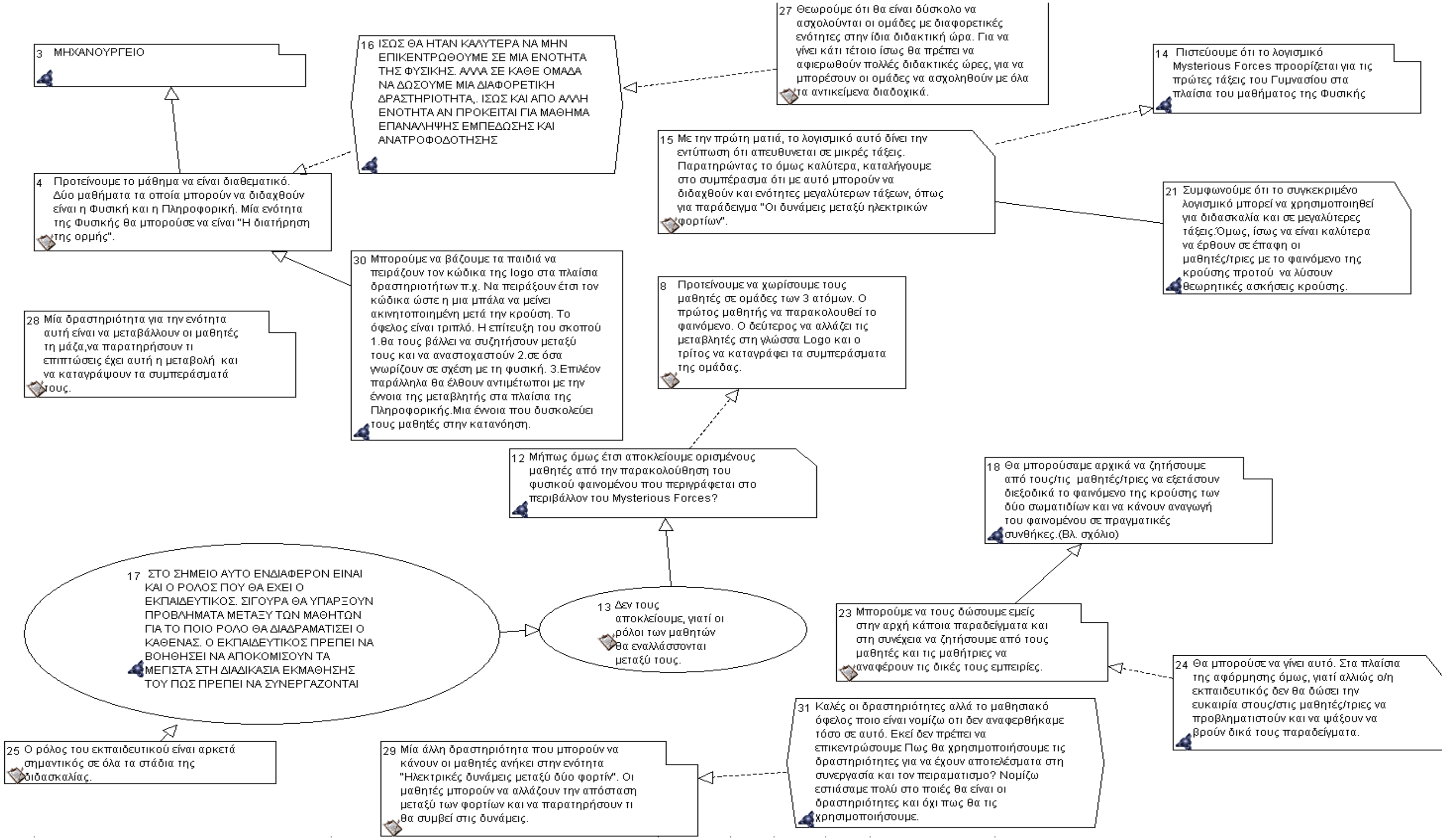
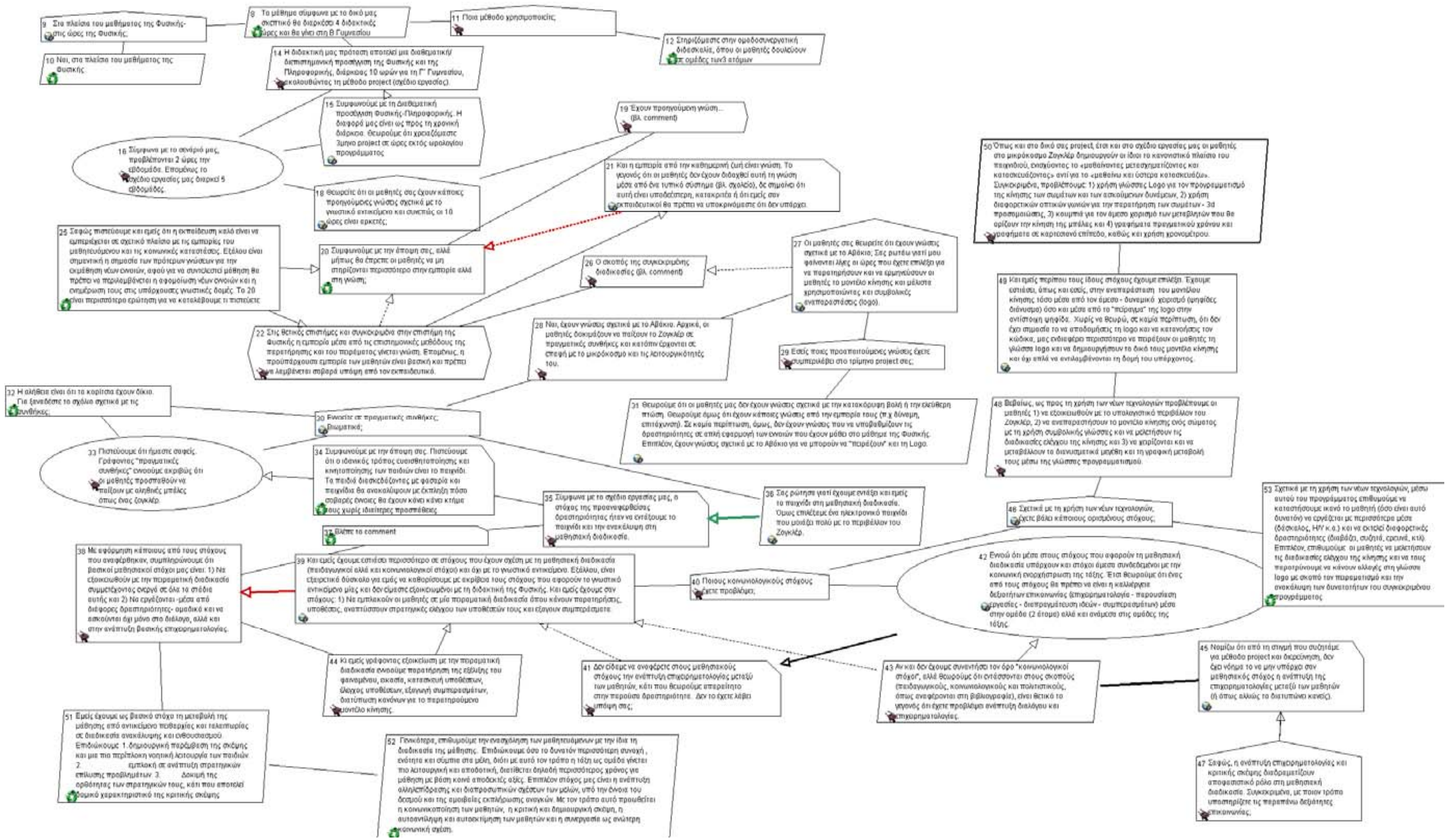
APPENDIX I: The Digalo e-discussions

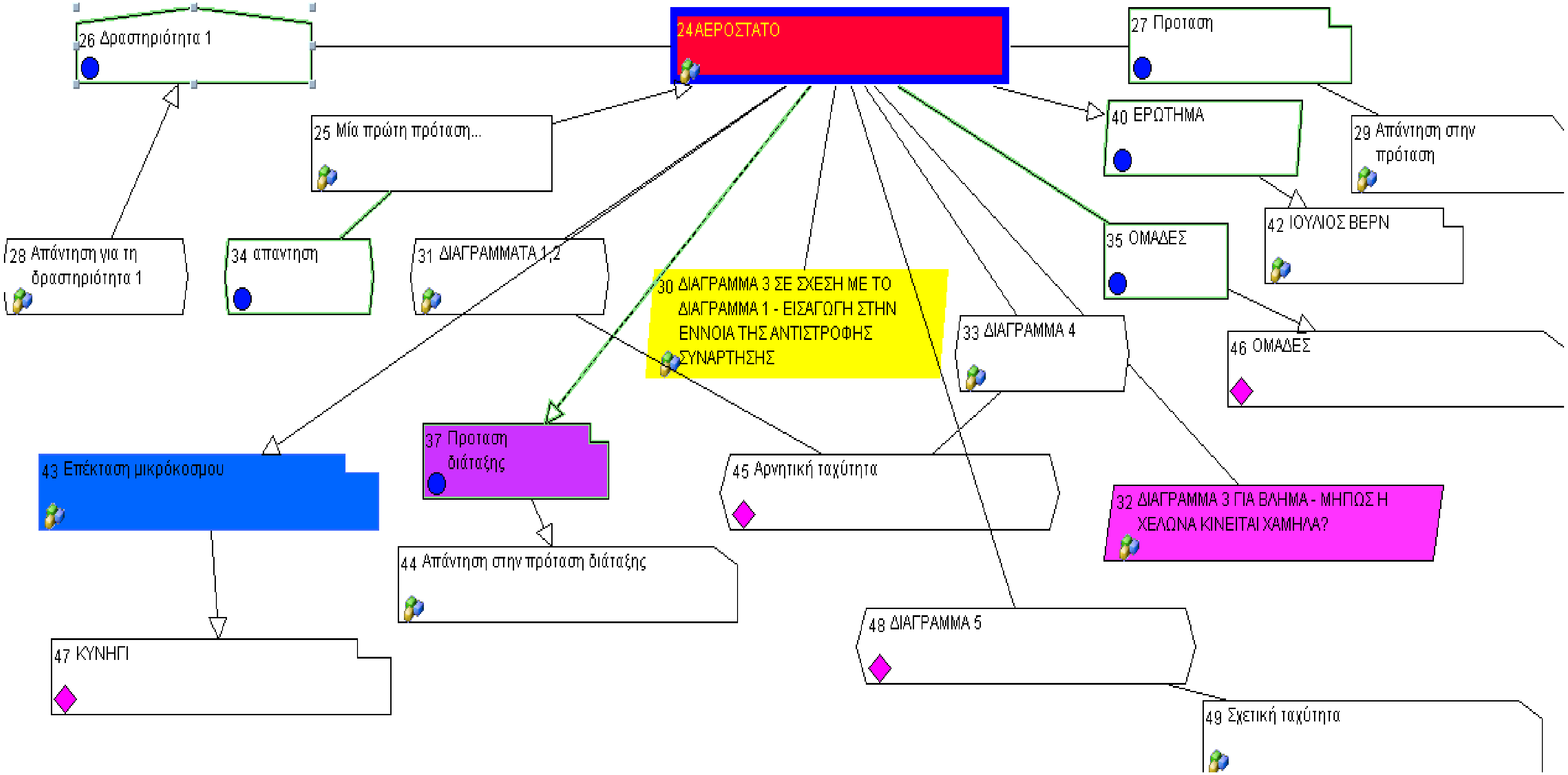
A part of the "Mysterious Forces" Map (ETL_Mysterious Forces_1)



A part of "The Juggler" Map (ETL_Juggler_2)

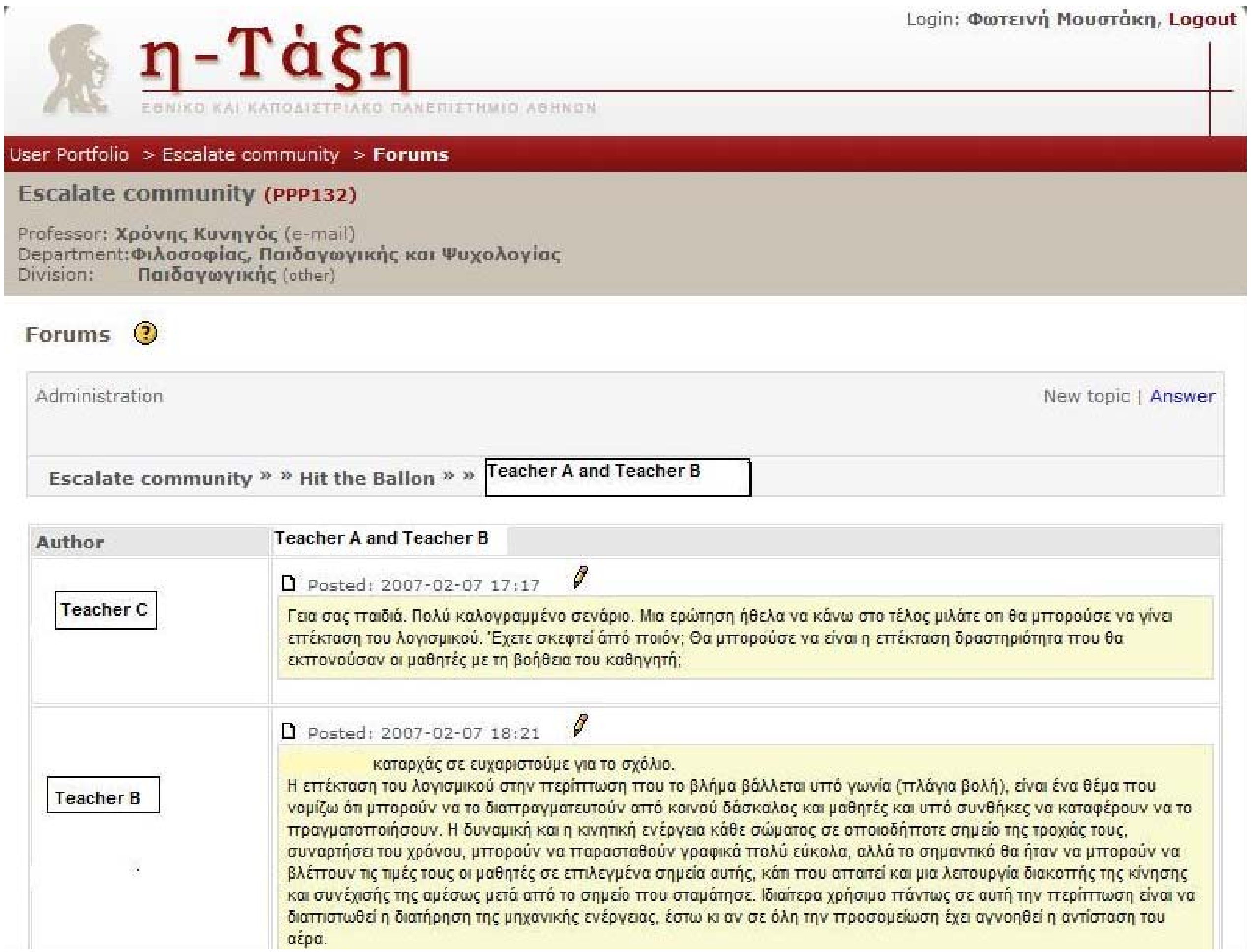


A part of "The Hit the Balloon" Map (ETL_Balloon_1)



APPENDIX II: The e-class discussions

Two teachers discussing on the activity plan



ESCALATE: The White Book

Chapter 7: Description of the experimentations in Greece

Sub-chapter 7b: The implementation at Rhodion Paideia School, Rhodes/Greece

Implementation of the case HIT THE BALLOON at the 1st grade of a private High School at the island of Rhodes Greece

K. Kontogiannis & C. Kynigos

Table of Contents

7b.1 The problematique

The study of bodies' motion is one of the most difficult objects of physics. Butterfield claims that the theoretical unraveling of the problem of motion is the most interesting challenge that the human intelligence faced for the last 15 centuries! (Butterfield, 1983, p.15). As Arons points out (Arons, 1990, p. 14) the fact that, despite the insistent efforts dated from the era of pre-Socratic philosophers, it is only during the 17th century that the frame for the study of moving bodies began to be shaped, is an explicit evidence of the complexity of the phenomenon and the difficulties that exist in its comprehension.

The students who, at the age of 12-14, come in contact for the first time during their science class with the concepts of motion, are expected to "comprehend the concatenation of kinematics' notions with the assistance of 2-3 pages of cryptographic text and of a short or extended oral presentation" (Arons, 1990). And as it has been proved, very few of them reach the goal after the relevant teaching (Trowbridge and McDermot, 1980 and 1981).

Apart of the complexity of the phenomena of motion and the abstruseness of the concepts involved, students trying to comprehend kinematics confront further barriers. The phenomena of motion are very familiar to them from their everyday experience. Thus, students are developing solid and resistant preconceptions about them and, as a consequence, multiple cognitive conflicts are produced during their study of the phenomena and a process for the redefinition of the meaning attributed to concepts and terms which were familiar to them evolves.

The key concepts in kinematics, which the students are expected to comprehend from their first contact with the subject during the first grade of junior high, are time moment, time interval, position, shift, displacement, velocity (average and momentary), speed, relative velocity and acceleration. All these concepts are widely used in our daily communication, although, some of them, with different meaning than the one attributed to them in the frame of science.

For example, in every day communication we say that "I will be there in a moment" and we mean in a small time interval, while in scientific language, "moment" is infinitesimal with no duration. Another example of ambiguity is the term "position". In everyday language position is synonym to place, although in scientific language position is a vectorial magnitude whose variation is the result of motion phenomena. Also, displacement in every day communication means "the action of changing place", while during the science class students are taught that displacement is a vectorial magnitude which is equal to the subtraction of the vector of the initial position from the vector of the final position. The whole procedure is hard for the students and causes a lot of difficulties to them. On the other hand the structure of the curriculum does take into account the problem of ambiguity: the emphasis is given to the memorization of the definitions of terms and not to their comprehension, so that the students distinguish the frames in which they use them.

Another problem emanates from the fact that, with kinematics, the students, for first time, come in contact with an accurate mathematic formalism, accompanied with meticulous formulations and complex graphical representations. Usually, they spent a lot of time and effort to comprehend "obscure mathematics" without relating them to the physics' concepts. In order to handle physical magnitudes in the frame of mathematical formalism, the students learn to use symbols. The use of symbols, as Arons remarks, causes extra confusion. For example, the same symbol (t) is used to represent the notion of "moment" and the notion of "time interval" and the symbol (s) is used to symbolize position, shift and (in the case of rectilinear motion) displacement. The confusion in the symbolism (which results from .the supposed need of simplification of formalism) impede students from clarifying the significance of terms and the correlations between them and thus, they use them indiscriminately. (Arons, 1990, p. 94)

Similar confusion is provoked from the symbolic representation of mathematical relations among physical magnitudes. For example, by determining acceleration as a=v/t impedes the discrimination between the momentary velocity and the velocity's change. The same remarks can be made for the correlation between other magnitudes, such as the relation between velocity and displacement (v=s/t) (Trowbridge και McDermot, 1981). In general the use of ratio for the determination of physical magnitudes is problematic for the students. As Trowbridge and McDermot observe, in the traditional teaching of kinematics the mathematical determination of magnitudes precedes the functional definition in the frame of physics and thus, the students learn to describe velocity as the rate of position and acceleration as the rate of velocity, but it is not clear what they actually understand when they say that these magnitudes express a "variation over time".

Finally, the graphical representations that are imported in the study of kinematics for the elucidation and the deeper comprehension of the physical magnitudes are confronted by the students as untranslatable abstractions and they are not connected with the relevant phenomena (McDermot, Rosenquist and Van Zee, 1987). Thus, the students are unable to draw a graphical representation related to a motion phenomenon which is not described in their book; neither can from the study of a graphical representation describe the phenomenon which drove to it.

Therefore, it is possible that students learn the definitions of magnitudes as they are formulated in their handbooks, use them as they have been taught in order to solve an exercise, manage to answer test questions, but nevertheless they have not accomplished to construct a relevant concrete conceptual frame. Researches have shown that even students, who obtain high marks in tests and assessment procedures in physics, maintain intact many of their initial ideas about the motion phenomena and relative physical concepts. (Halloun, Hestenes, 1985a. and 1985[b], Peters, 1981).

To some extend this is due to the structure of the curriculum and to the didactical procedures which, at least in the Greek educational system, are aiming to train the students to learn the "syntax" of science and not the scientific phenomena and concepts: the notions are substituted by their symbols, which the students are expected to learn and handle in a specific way, even if they do not accomplish to comprehend their significance.

7b.2 Background of the national context

In Greece the responsibility for the supervision of primary and secondary education belongs to the Pedagogical Institute, which is a public organization acting as consultant to the ministry of education. Pedagogical Institute develops the curriculum for every discipline which is taught in schools, approves the textbooks and the educational material that will be used, defines the school program, sets the criteria for teachers' hiring, develops the programs for in service and pre-service teachers' training and gives instructions to the teachers about what is considered as good didactical practice.

The mainstream teaching in schools puts the teacher in the center of the procedure. He or she delivers lectures about the taught subject, answers to the students' questions, define the homework for the next lesson and examines the work that was assigned from the previous class, which the students have prepared at their homes. Usually the only educational material used is the official textbook and it is only recently that Pedagogical Institute has approved the development of supplementary educational tools such as specific software, laboratory equipment and worksheets etc.

In secondary education Physics is taught from the second year of junior high school till the last year of high school, for 2 or 3 teaching periods per week. The compulsory curriculum includes Newtonian Mechanics, Wave theory, Electricity, Electromagnetism, Thermodynamics and an introduction to modern Physics. The curriculum is mostly oriented towards theory and includes very few laboratory and experimental activity. Big emphasis is given to the accuracy of formulation, the use of scientific language and to problem solving.
Kinematics in Greece is taught twice: for two months at the 3rd grade of junior high school and for one month at the 1st grade of high school. The curriculum is similar for both grades and the distinction is that at high school problem solving is included while the students in junior high deal mainly with qualitative questions and don't use mathematical representations. The curriculum for both grades includes rectilinear normal and accelerated motion, circular motion and projectiles. Although some experimental activities are foreseen, the majority of teachers skips them because they find them very difficult and time consuming.

7b.3 Background of the institutional context

The "Hit the Balloon" case was implemented in two classes of the 1st grade of high school at a private school at the island of Rhodes. The school was established at 2002 and it has 500 students and 60 teachers at elementary and secondary level. The personnel of the school is consisted mainly of young teachers, who are willing to enrich their teaching with innovative techniques and media. Many of them have got a master's degree or a PhD diploma.

The school is organizing training programs for its educational personnel about the multidisciplinary learning, the use of ITC in teaching, the development of extra curricular activities etc. They are implementing a program with Special Interest Groups of students who, divided in groups of 8-12, for 2 hours per week work on a subject in which they are interested. In the frame of this program 4 groups relevant to science were established, with interest in ecology (the quality of water in the island of Rhodes), astronomy, robotics (constructions with the Lego Logo kit) and experimental physics (use of Micro Computer Based Laboratory for the study of specific phenomena in Mechanics). Four of the students who participated to the last SIG participated as teacher assistants to the implementation of the "Hit the Balloon" case.

For bettering the educational achievements in science teaching, the school has added a supplementary school period at 1st grade of high school, which is devoted to experimentation in the laboratory; this is the period that we used for the implementation of the case.

7b.4 Preparatory work for the implementation

Details about the principles on which the case “Hit the Balloon” is designed may be found in the chapter about Microworlds of this book. The general idea is that with the use of Microworlds in science teaching we aim to encourage students to discover the phenomena, instead of learning how to describe them by reproducing the information given to them by their teacher. This specific microworld creates a virtual environment with the characteristics of a “closed world”. In this environment the bodies behave following the rules deriving from its characteristics and, thus, the students may “investigate the phenomena” represented in the microworld through inquiry with the microworld.

The use of microworld as an instrument for inquiry facilitates the connection of experience with theoretical knowledge and highlights the interrelation of the body’s behavior with the features of the virtual world. The questions posed to the students are usually open and don’t have a unique answer. Thus, the microworld promotes the collaboration between students and the argumentation about various aspects of the phenomena under investigation. As a consequence the social orchestration of the implementation differs a lot from the setup of frontal teaching; the students, divided in groups of 2 or 3 persons, are sitting in front of a computer where the microworld is loaded. They use one worksheet per group and the appropriate media for exchanging and recording their arguments.

The teachers, who will implement this didactical procedure, must be familiarized with it, since they don’t use it in their everyday practice. That’s why at March 2006, one month before the implementation at school, we organized a training program for the teachers who were supposed to use the case with their students.

The training program had two distinguished subjects. Initially DIGALO was presented to all the teachers of the school. After the presentation, which lasted one hour, a discussion followed with the teachers in order to record their opinion about the advantages and disadvantages of DIGALO as a tool for monitoring an argumentation procedure, in comparison with other media such as a chat room or flipchart and marker. The initial thought was to install DIGALO at the computer lab and use it for the discussion, so that the teachers would have the opportunity to use the software in practice. Unfortunately due to technical reasons this could not be done within the available time.

The conclusion from the discussion that followed was that the advantages of DIGALO are its flexibility, the possibility of saving and recalling the charts at any time and the fact that the students might find it interesting since they like working with computers. On the other hand the majority of them found that the use of DIGALO for monitoring the argumentation would cause many problems in comparison with the use of flipchart and marker. They believe that it is time consuming, since the students must write extended text at every box instead of writing a couple of words as they could do if they used a flipchart, it is not easy to highlight something at any time, as we could do if we used a marker, the organization of the discussion in the digital environment is more complicated than in front of flipchart and that it is difficult for the teacher to study the charts produced by the students, since he/she must work with a computer instead of working with the sheets of the flipchart. In general, they were not convinced that the benefits for using DIGALO in everyday practice, in order to do something that could be done very well with more traditional media is worth it. We believe that if the teachers had the chance to use DIGALO a few times or if they could attend a more extended training program for its use, they would have more positive attitude for its use in the everyday practice.

The second subject of the training program was addressed only to the Physics teachers whose classes would participate to the implementation. It lasted 5 hours spread in 2 days and it was attended by the 2 Physics teachers and the principals of High School and of Junior High who, both, they are physics teachers as well.

The attendants used the microworld in order to answer the questions of the worksheet and made their remarks about it. The teachers agreed to be present during the implementation and assist the researcher, but said that they did not feel secure enough to have the prime role. They expressed their doubts about the capability of their students to use the microworld in order to deal with complex questions like the graphical representations of relative velocities. Also they stated that their students could not use at the same time two software (DIGALO and e Slate) since it was the first time that they would use a personal computer in a class other than informatics.

After that it was agreed to makes some amendments to the subjects negotiated in the worksheet and to allow the students instead of using DIGALO, write down their arguments to the blank space of their worksheet. Finally it was decided that the whole procedure would be videotaped and that in each class we would choose a three-member group which would be monitored in details (video and audio taped).

7b.5 Description of the social context of the implementation

The implementation took place from 2/5/06 to 5/5/06 and involved 2 classes of 1st grade of High School (ages 15-16 years). The first class had 16 students divided to 5 groups of 2 members and 2 groups of 3 members and the second class had 17 students divided to 4 groups of 2 members and 3 groups of 3 members each.

At this period in Greece the schools have practically completed the coverage of the curriculum and they are in the middle of the preparation of the final exams which take place from 15 of May till the 10 of June. Especially in the case described here, the students had just returned in school after their Easter holidays.

The ordinary teachers of the classes had attended the training program about this specific microworld, but they were not eager to implement the case with their classes alone. So it was decided that the researcher of the ESCALATE team would act as the class teacher and the teachers would assist him. Thus during the implementation the school teachers were answering student’s questions, they were supporting them in order to complete all the tasks described to the worksheets and they were monitoring the argumentation among the members of the groups, helping the students to remain focused to the subject they were discussing. On the other hand, the introductory presentation of the course was done by the researcher, who, as well, gave the instructions about the worksheet and the work project.

The school's administrators attended the implementation and had a very positive attitude. They believed that the participation of the school to the project was a good opportunity to open the discussion with the school's teachers about importing ITC into everyday educational practice.

The students who participated to the implementation were very enthusiast about it. They collaborated intensively in their teams trying to express an opinion about all the questions of the worksheet, they were asking questions in order to clarify what was not clear to them and in some cases the teams were competing, trying to give sophisticated explanations to the most interesting questions.

7b.6 The artifacts used

For the implementation of the case *"Hit the Balloon"* the students used the microworld and the worksheet, which both can be found at the ESCALATE portal. Every group used one computer to run the microworld and one worksheet which they completed and delivered at the end of the procedure. For the evaluation we used a 2 pages test which was completed by all the students at the end of the implementation. Finally for the monitoring we used two video cameras, an audio tape and a voice recorder. The first camera was taping the class as a whole and was following the teacher, the second camera was focused on one group of students and the audiotape was taping the discussion between the students of this group; the voice recorder was used by the researcher to record some remarks during the implementation.

7b.7 The description of the course of the activities themselves

The implementation lasted for 6 school periods and it was divided in 4 parts as it is shown to the following table.

Part	Duration	Content
Introduction	1 period	Familiarization with the software Recapitulation of kinematics
The Flight of Balloon	1 period	Study of the Rectilinear and Regular motion.
Throwing a stone	1 period	The study of decelerated motion
Hit the balloon!	2 periods	Study of the meeting of the two bodies Study of the relative motion
Conclusion	1 period	Evaluation Annotation

The **first period** was devoted to the familiarization with the software and to the general description of the case. The groups were formed and a quick recapitulation on kinematics was done, in order to remind to the students the basic laws and theorems. The students worked with question 1 of the 1st part in order to learn how to use the buttons and the sliders.

At the **second period** the students worked with questions 2, 3, and 4 of the first part. These questions are focused on the representation of magnitudes with the use of graphs. The students run the microworld many times and they discovered options that were not presented to them, such as the possibility of constructing a graph of peculiar shape by changing the sliders while the body is moving. Especially with question 3 the majority of the students referred to the researcher or to their teacher for assistance.

At the **third period** the students worked with the 5 questions of the second part which refers to the decelerated motion. The available time was adequate for the majority of the groups although they needed some assistance by the instructors for question 4.

The **forth** and the **fifth** periods were devoted to the study of the meeting of the 2 bodies and the study of the relative motion. Practically all the students managed to complete the questions concerning the meeting (questions 1,2,3,6 and 7) and only 3 groups had enough time to deal with questions 4 and 5 which refer to the relative motion

7b.8 Main observations at all levels and evaluation

- ***Observations about the general attitude, participation and involvement.***

The overall impression of the implementation was that the majority of students were involved with the use of the microworlds, they tried to investigate all the questions, they exchanged arguments in an intense way, giving interesting and in many times unconventional answers. Many of them denied to leave for their brake in order to complete the worksheet of their team and in one class a competition was organized among the students' teams about which team would give the most complete and unconventional answers.

This positive attitude was not observed only among well performing students. We observed that students having difficulties with science class, although initially were hesitating to use the microworld and express their opinion about the issues under examination, they tried to participate to the negotiation with their team mates and after a while they started to experiment with the microworld and deepen their involvement. The most characteristic case was student A.K. His academic profile was very weak in science, although (as his teacher described him) he was very eager to participate in school activities. Thus he was chosen by his teacher to act as assistant to us, and be responsible for the videotaping of what was happening in the classroom. After the first period was completed and AK has completed the videotaping, he asked to participate at a team and try to work with the microworld. Actually, during the next periods he participated at a team being the third member of it and not only he took control of the team's computer, but also he gave some very accurate and clever answers to difficult questions. When he was asked during the interviews to describe his experience, AK said that he decided to participate energetically because he realized that it was not expected from him to remember and use formulas and mathematic calculation and because he

"understood for the first time what was going on".

Also he said that he liked that there were not any questions with unique answers and he had the impression that

> *"I only had to use my common sense and intuition in order to contribute to the negotiation*".

On the other hand in every class there were about 3-4 students who obviously did not participate at all. They left their teammates alone to experiment and complete the worksheets and when interviewed they declared that they found the microworld environment "not interesting at all", "boring" and "confusing". In one specific case, both members of the team had the same attitude: of working with the microworld and negotiating on the questions of the worksheet, they were trying to "hide" from their teacher and serf the internet. After several warnings they were asked to leave the classroom since their attitude was actually very annoying.

After the implementation, in collaboration with the class teachers, we discussed the behavior of the students in order to find an explanation for the "negative" attitude of this small group. After studying their academic profile we saw that all of them were very weak academically, not only in science but almost in all academic disciplines. Besides, their general attitude in school was problematic: they never volunteered to participate in any school activity and some of them had misconduct problems.

As a conclusion we may say that the microworld environment, the open ended questions which are not leading to a unique answer, but are rather promoting inquiry and investigation and the idea of negotiation among the teammates in order to arrive to a conclusion about the questions that they investigate, is very attractive for the majority of students: even students who feel weak in science and avoid participating in laboratory activities or in discussions during the science class, are encouraged to be involved and take an active role in their team trying to contribute with ideas and arguments while investigating the questions of the worksheet.

- ***Understanding of the described phenomena***

The remarks and the comments at this paragraph refer to the relative questions of the worksheet. Related to the description and understanding of phenomena in kinematics are the questions 1, 2 and 3 of the section about the decelerating motion of the stone and the questions 1, 2, 3 and 6 of the third part which is about the meeting of the two bodies. These questions demand from the students to describe what they observe, define the parameters that influence it and predict the evolution of it in correlation of the alteration of the parameters.

The combination of the representation of the phenomenon and of the graphical representation oh the correlated physical magnitudes, enhance the deep understanding of the phenomenon and bring to the front stage hidden aspects of it, which are hard to be observed in the lab or even in real life.

For example at question 1/(2^{nd} part), we ask the students to describe the motion of the stone when it is thrown upwards. The usual answer is that it is going up with diminishing velocity and after it reaches the upper point of the trajectory, it falls down with augmenting velocity. In their description many teams managed to exceed their description, incorporating in it the sign of the velocity as an algebraic magnitude. In other words, since they observed at the sane tine the motion of the stone and the variation of its velocity, they realized that during the fall the velocity is negative. The most common description was that

> *"the velocity of the stone (during the fall) is augmenting towards the negative direction"*

but in 3 cases the description was more accurate. For example one group described the phenomenon saying that

> *"during the fall the velocity is still diminishing and becomes negative. The displacement at the same time is diminishing and finally the body returns to its initial position having the same measure of velocity as the initial"*

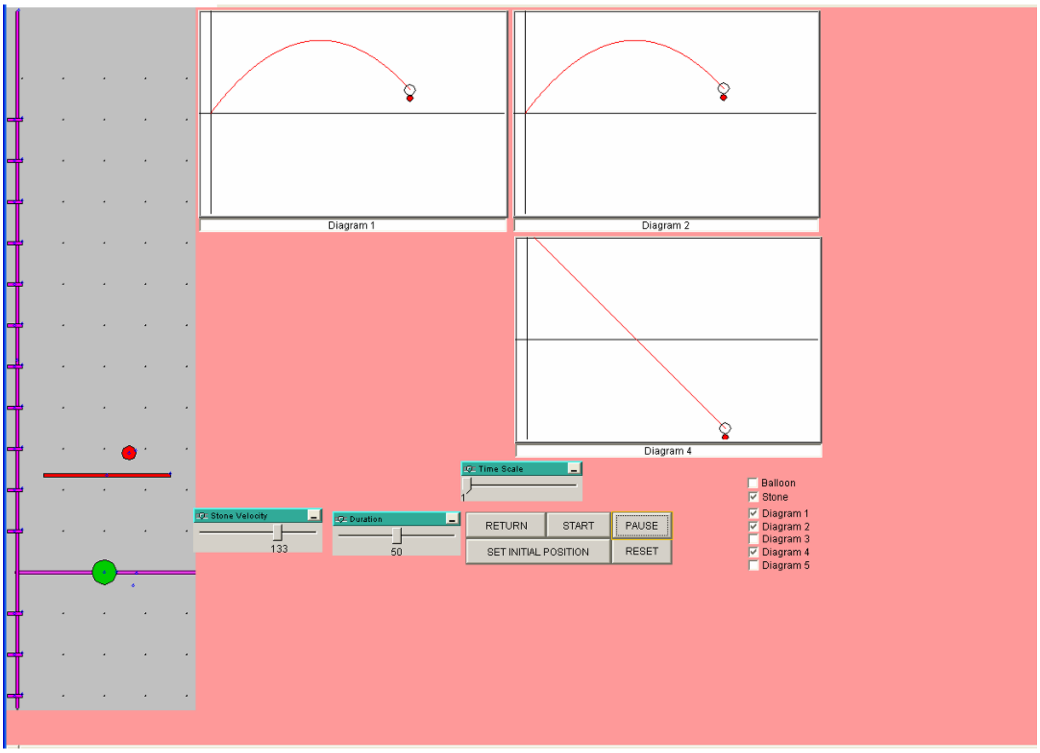


Fig.1 *The students realized that the velocity is diminishing during the fall of the stone*

When dealing with question 2/(2nd part) students realized that the gravitational acceleration determines the rhythm of the velocity's decrement. They did not necessarily related **g** with the slope of the graph but they understood that no matter how big is the velocity it

> *"permanently loses a certain amount every second"*

Another point that was easily clarified through teammates' negotiation was the relation between time of ascending and time of descending (puestion3/part2). These time intervals are equal in any kind of uniform motion. Usually, students of 1st grade Junior high know this property of uniform motion, either by instinct either as an immediate consequence of the mathematical analysis of the motion.

With the microworld, almost all the teams worked in the same way: initially, they tried various values for the duration slider till they managed to make the phenomenon "stop" exactly at the moment when the graph of velocity vs time reaches the axis of time. The determined the "duration" they found as the " ascending time" of the stone. . In order to find the time for the stone to come back on earth, they did not experiment, but they set the duration slider directly at the double value and the majority of the teams, in order to calculate the time for the rest values they consider that this proportional to the initial velocity.

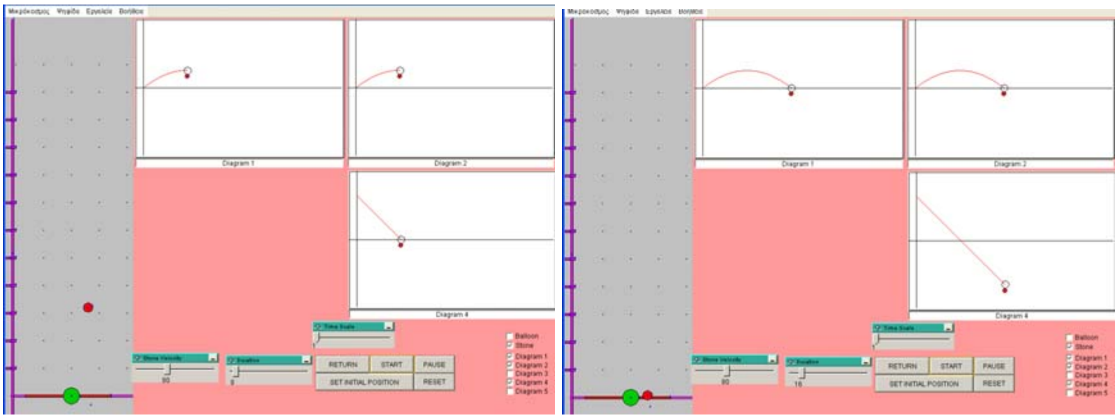


Fig.2 *Through a trial and error procedure the students calculated the time of ascending and the time of descending*

Similar observations were made when the students were studying the phenomenon of the meeting of two bodies. The phenomenon is more complex and although all the teams worked with the questions 1 to 3 of the third part, only few of them (1 or 2 teams per class) gave complete answers. The third question of the part asks the students to set the values of the parameters at the microworld environment so that the two bodies meet once or twice. The negotiation between the members of a team when they investigated the situation of the singular meeting is interesting

***St1**. When the bodies meet the lines intersect. (he saws the displacement vs time graph). Thus for one meeting we must obtain one intersection point.*

Student 2 changes the delay slider and make some trials till the stone's displacement graph becomes tangent to the balloon's displacement graph.

***St2.** This is the case*

***St.3** Yes, but when the bodies meet once shouldn't the stone be still? (she moves her hands pretending they are the stone and the balloon) You see: when the stone just touches the balloon, it is still and then it falls.*

***St.2** But you are not moving your hands in the right way. How do we know that your moves are exactly the moves of the bodies.*

***St1.** Look at this graph. (He saws the velocity vs time graph) The two lines intersect.*

***St3** So what? What does it mean?*

***St2.** It means that at the moment of the meeting they have the same velocity.*

***St.3** But don't you agree that the stone must be still? When it comes and just touches the other body the next moment it will go back. So at the moment of the meeting it must be still.*

> ***St.1*** *No. It seems to be still because it has the same velocity as the other body. That's why the velocity graphs intersect. When a bullet comes to fit me and I run at the same speed with the bullet, the bullet will never hit me and if I look at it I will seem to be still. That is what you are saying.*

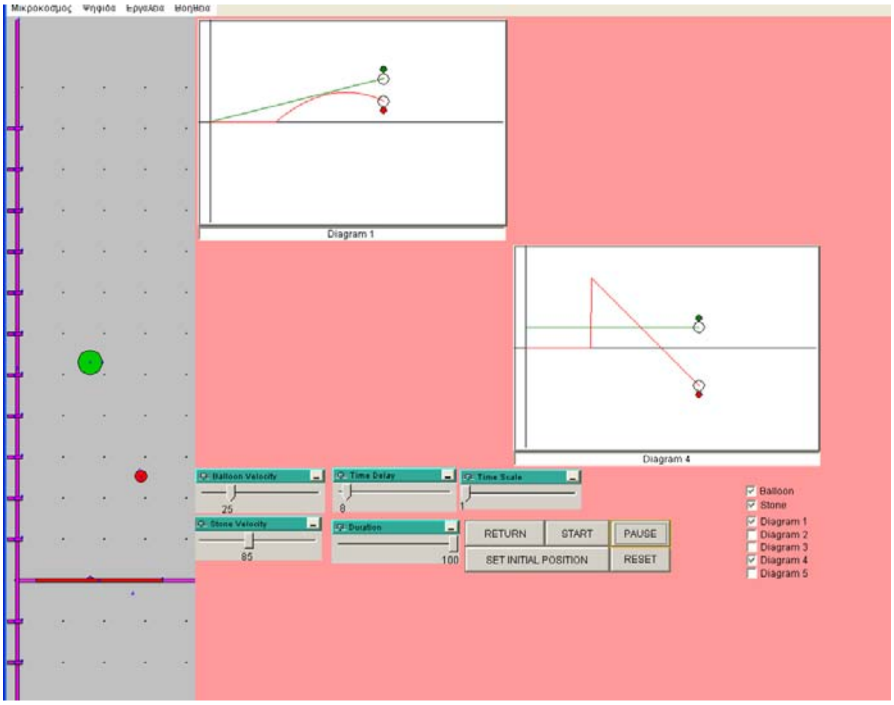


Fig.3 *The study of the situation when the two bodies meet once, help the students to understand that at the moment of the meeting the balloon and the stone have the same velocity*

Thus, we may conclude that the digital microworld in combination with the argumentation procedure, help the students investigate many aspects of the phenomena and discover correlations between magnitudes that are not obvious when they observe the same phenomenon in its physical context.

- ***Elucidation of concepts***

The graphs 1 and 2 of the digital microworld, refer to the concepts of displacement and position correspondingly. The distinction between the two concepts is difficult because it is based on the mathematical convention of the point of reference (the point were tha position is considered to be 0).

The question 3 of the first part of the worksheet is devoted to the distinction between these two concepts. It was easy for almost all the teams to understand the difference between the two graphs and answer that

> *Graph 1 shows the space covered by the body while graph 2 shows its distance of the body from the red line (the student were told to transfer the red line which is available to them in the microworld at the initial position of the body, in order to visualize it).*

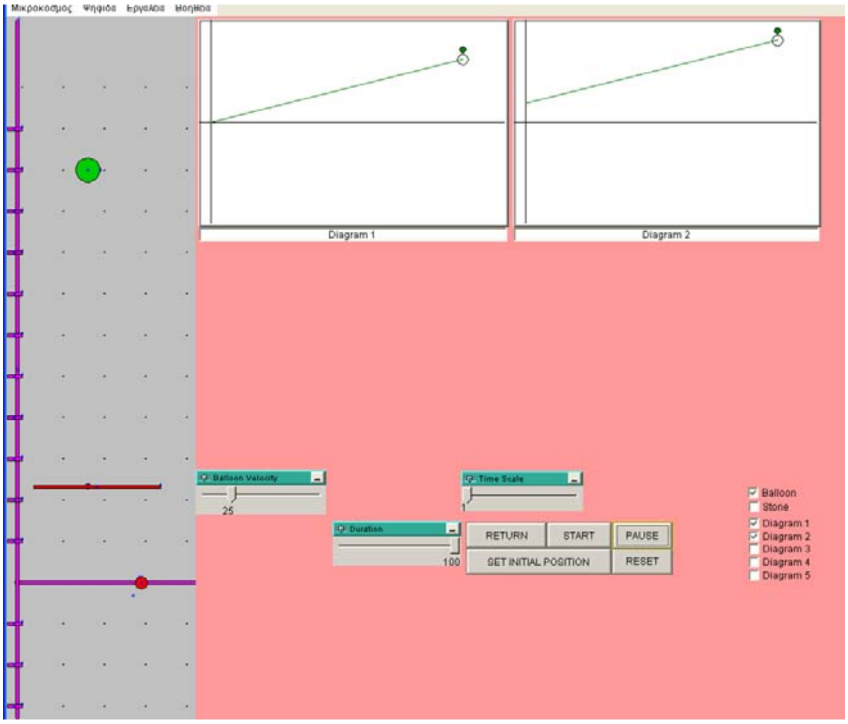


Fig.4 *The comparison between graphs 1 and 2 help the students clarify the difference between position and displacement.*

Despite this fact the students did not manage to transform this distinction to mathematical relations. During the interviews after the implementation, when discussing the answers to this specific question, the students we asked to write the mathematic equations that corresponded to graphs 1 and 2. All of them gave the correct answer for graph 1 (s=v.t) but no one answered that the equation for graph 2 is $x=x_{initial}+v.t$

Another concept that we wanted to elucidate was the concept of “relative velocity”, videlicet the velocity of the stone measured by the balloon and vice versa. Questions 5 and 6 of the third part of the worksheet refer to this specific concept. Only three teams in total tried to investigate this issue. Those teams were not representative since members of them were some of the more qualified students in science.

These students correlated the relative velocity graph (graph 5) with graph 4 which refers to the absolute velocity. For example they saw that when the absolute velocities are equal the relative velocity is zero and they explained the negative relative of the balloon when the stone is moving faster than it

> *“because if you are on the stone you see the balloon moving back”*

Nevertheless, we think that their comments were rather based on their preexisting knowledge on the subject, than on their experimentation with the microworld. In general we consider that the students did not investigate those questions that were very demanding and complicated. The reason was the luck of time that did not allow them to familiarize well with the microworld, the fact that the implementation took place a couple of days before their Easter vacation and that’s why they could not concentrate and focus to their work and that some of the questions about the meeting of the two bodies exceeded the academic level of the majority of the students.

- ***Understanding of graphical representations***

Practically, all the questions of the worksheet are related with the interpretation of graphical representations of physical magnitudes. At a first level the students are asked, after studying the shape of a graph, to find out which is the represented magnitude. For their study, during the implementation, the students were encouraged to document their answers without using mathematical relations, but only by correlating the representation of the motion with the shape of the graph.

The question 4 of the 1st part demands the comparison of graphs 1 and 3. The first is the diagram of displacement vs time and the second is the graph of time vs displacement. The students answered to the question examining the slopes of the two diagrams.

St1 (pointing at graph 3) "Why is this lower than the other"
St 2 "I don't know. But they change in the same way"
Teacher: "Try to change the velocity"
St. 1 "When the velocity is bigger this (graph 1) goes up and the other goes down"
St.2 "OK This (graph 1) is displacement vs time. What could graph 3 be?"
St.1 "Again the magnitudes should be distance and time, but the seem to be inverted"
St 2 "Yes. Because here, for the bigger is the velocity, the smaller is the slope. This means that for the same value at the horizontal axis we get less value at the vertical axis. The only magnitude that becomes smaller when the velocity augments is the time to go at a certain point.

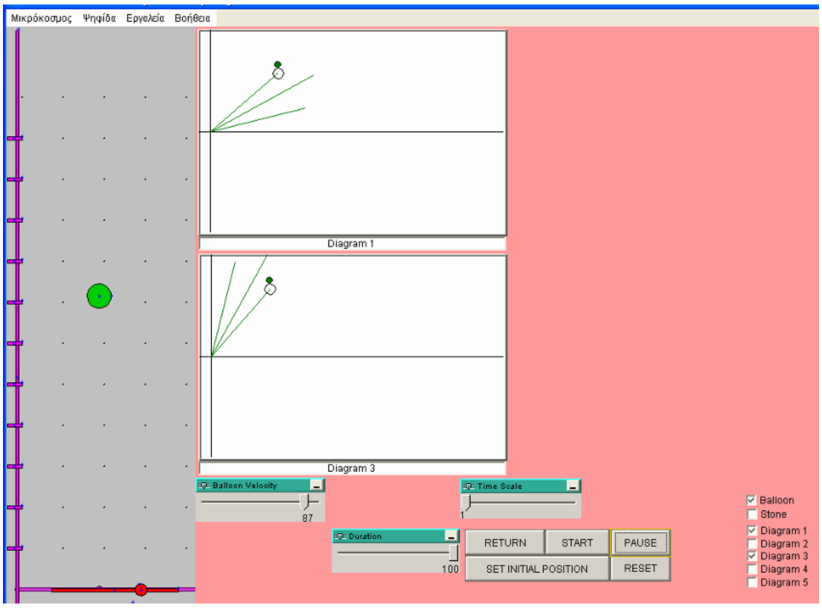


Fig.5 *The alteration of velocity influences the slope of diagrams 1 and 2*

At part 3 the students used the diagram of the displacement vs time, in order to study the phenomenon f the meeting. As we have already described, at the same moment they had the opportunity to analyze the shape of the diagram and to correlate it with the diagram of the velocity vs time.

7b.9 "Good/desirable" practices, lessons learned, and educational implications.

The most of our conclusions from the implementation of the "Hit the balloon" case were described in section 8. Here we will present some remarks about the problems we met during the implementation and some suggestions for the best implementation.
The environment of the digital microworld is quit demanding. Its use is not complex, but the students must experiment with the parameters. Thus, they must create a pattern for the experimentation, but they are not familiarized with this procedure. At this point they will need the support from their teacher.

The exchange of arguments among the teammates, who are trying to find the answers to the questions of the worksheet, is possible to become chaotic. The students change the parameters of the microworld and then they observe various aspects of the investigated phenomenon. Many times two or three members of the team focus at a different aspect and as a consequence, instead of communicating, they speak about different things. Thus at the beginning of the implementation the teacher must give clear instructions to the students that they must focus at only one aspect of the phenomenon each time trying to arrive to a clear conclusion.

Another difficulty is that the students study the graphs representing the magnitudes which are dominating the phenomena, without using any mathematical relations. This is desirable in the sense that we want to help the students relate the shape of the graphs with the behavior of the bodies and not to a mathematic formula. On the other hand, mathematical analysis is always indispensable when we study the natural phenomena. Thus, we must not consider this microworld as the unique didactical tool when we teach kinematics.

The last problem we faced has to do with the time disposed for the implementation in combination with the complexity of some questions. As it was previously said the environment and the whole procedure is demanding and normally the students are not used to study science this way. So, during the implementation it was proved that the three periods foreseen for the two first parts of the worksheet were not enough. As a result, practically the students did not spend enough effort to answer to all the questions of the third part. On the other hand some of the questions and especially those who referred to the relativity of motion were proven too difficult for the academic status of the students, who under the time pressure they had, did not try at all to solve them. Thus, we conclude that the first step when we design the use of such a case in actual classroom conditions, is to choose a small number of questions, compatible with the academic level of the majority of the students, to be investigated and be sure that the students will have enough time to become acquainted with the environment and handle the questions

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ESCALATE: The White Book

Chapter 8: Description of the experimentations in Switzerland & Italy

Anne-Nelly Perret-Clermont, Nathalie Muller Mirza, Jean-François Perret, with the assistance of Sheila Padiglia

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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 project[4]). 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

Nathalie Muller Mirza[5]

In this text, we shall present implementations of two scenarios (or cases): the first one is called the "Storm case[6]" and the second one the "Digalised Euglena[7]" 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 developped by F. Bonvin & F. Stettler in the frame of the course « Argumentation and learning ».

[7] A case called « Euglena » was initially developped 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 pupils[8].

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 inter-personal 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.

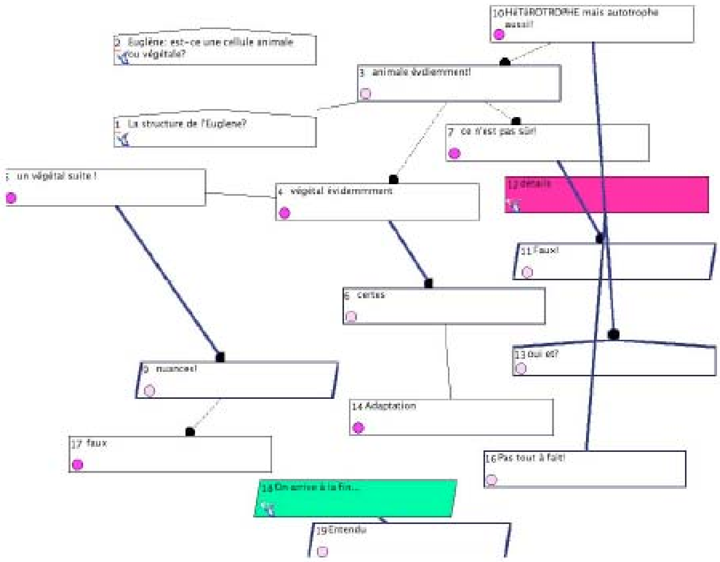

Figure 1: University students Argumentative map with Digalo

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)

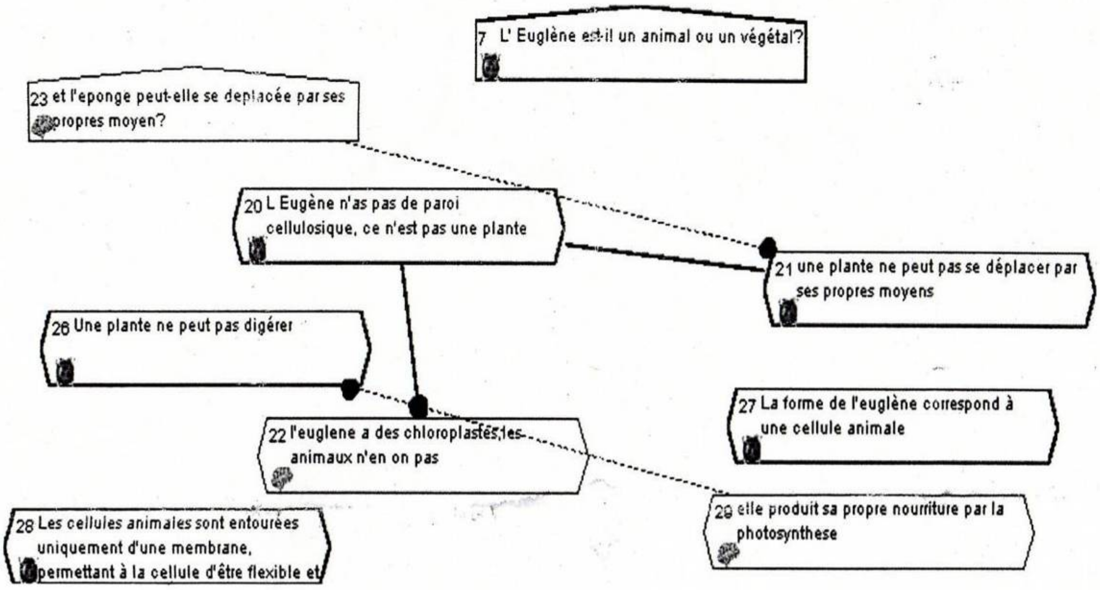

Figure 2: Secondary classroom Argumentative map with Digalo

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 choloroplastes, 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 is it 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);

- o 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 to[9]:

- 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 here[10].

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

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[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 places[11], 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 CO^2 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:

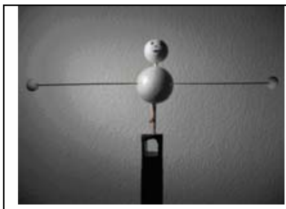
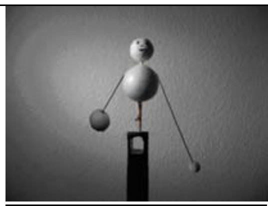
<u>Phase 1: Observing and discussing</u>
The pupils are invited to observe a set of different tightrope walkers (that have different colours, materials, size, weight, etc.). Then the teacher selects two tightrope walkers (one

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:

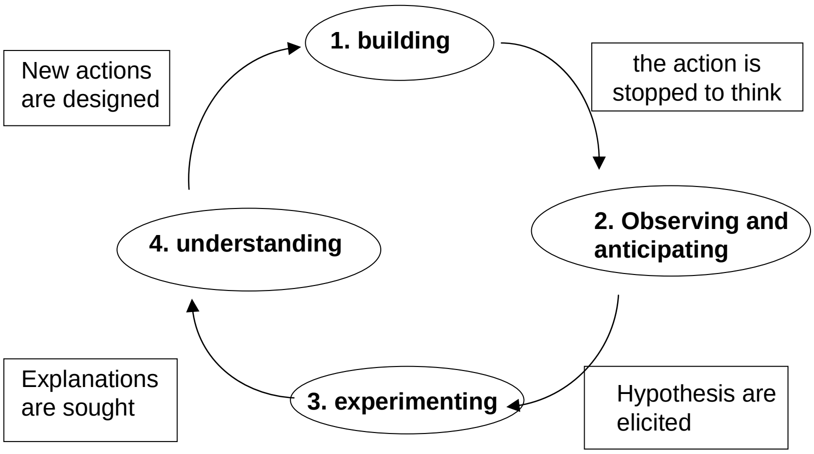
Phase 4: Analysing some arguments
A set of different written arguments is presented to the students. They have to decide, in small groups, which ones are right and which ones are wrong.

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.

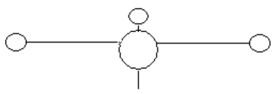
This led us to film two groups of first-year University students when confronted with this problem. The two dyads spent 30 and 50 minutes working on it. The two discussions were transcribed.

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).

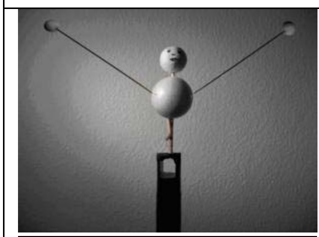
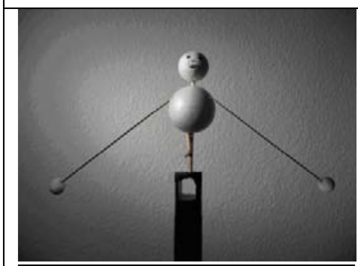
On the first attempt the pupils often manage to make a tightrope walker figurine keep its balance by imitating the figurine presented by the teacher during the first stage. The teacher encourages them to try new configurations (« there are several ways to ensure that it maintains its balance »).The pupils 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.

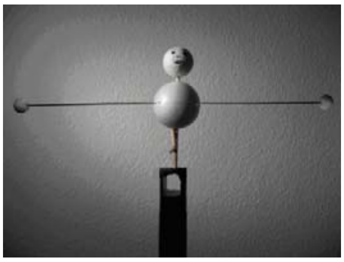
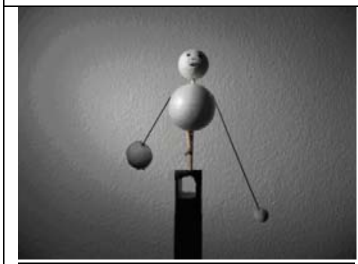
Third stage : Picture analysis

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 :

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

 Photo 5	« No, because it's too long » « No, because the weights are in the middle of the body » « No, it doesn't keep its balance because the weights are in the middle of the body» « No, because the arms are too long and too heavy compared to the body »
 Photo 6	« I think it doesn't keep its balance because of the inclination of one arm downwards and of the other upwards» « I don't think so, because one arm points upwards and the other one downwards »
 Photo 7	« Yes, because the weight is equal, a bit larger and thinner on one side and a bit smaller and longer on the other » « No, because neither the weights are similar nor the lengths» « No, because they have neither the same weight nor the same length »
 Photo 8	« No, it is the same length, but not the same position » « No, there are the same weights but they are not positioned at the same place » « No, the weights are the same but they are not correctly distributed »
 Photo 9	« Yes, because there are big differences » « Yes, I think it keeps its balance because the weight isn't much different » « It is balanced, because the arms are close to the small wooden stick (the foot) »

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.

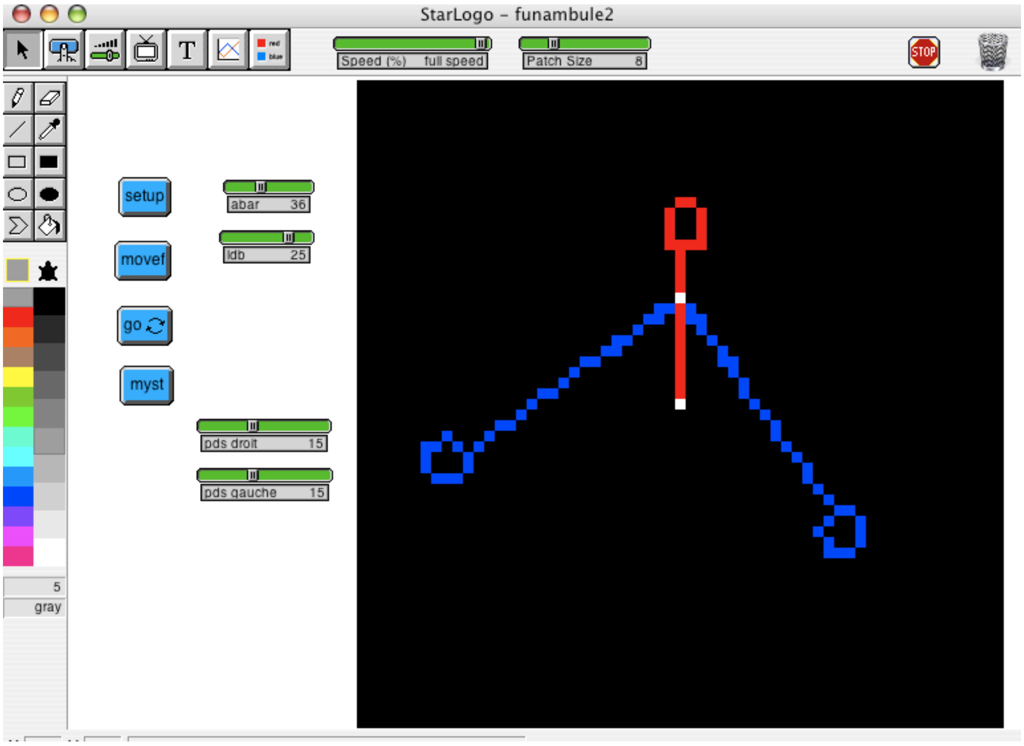


fig 1. The tightrope walker and his pole

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

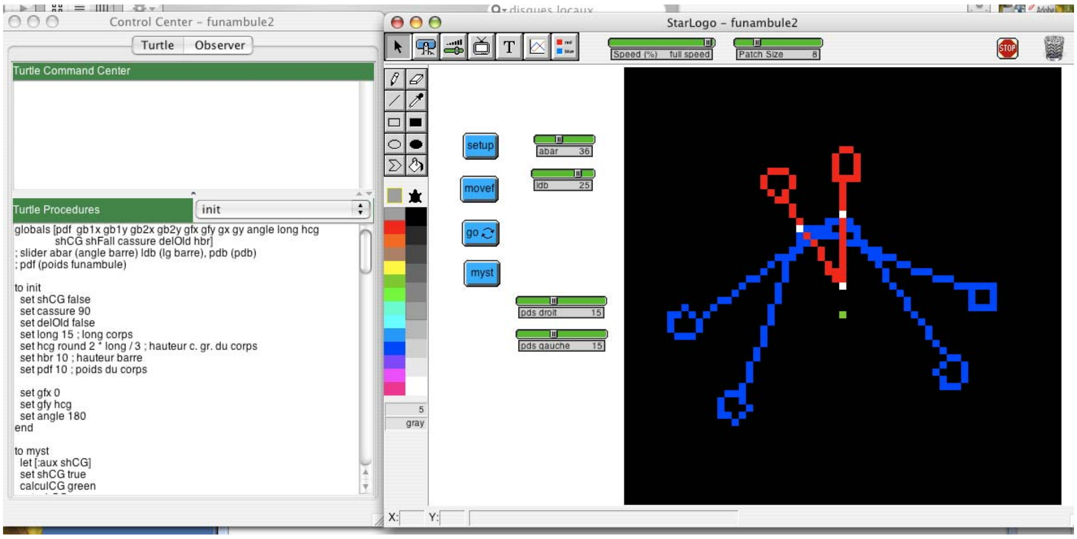


fig 2. The tightrope walker in a position of equilibrium

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.

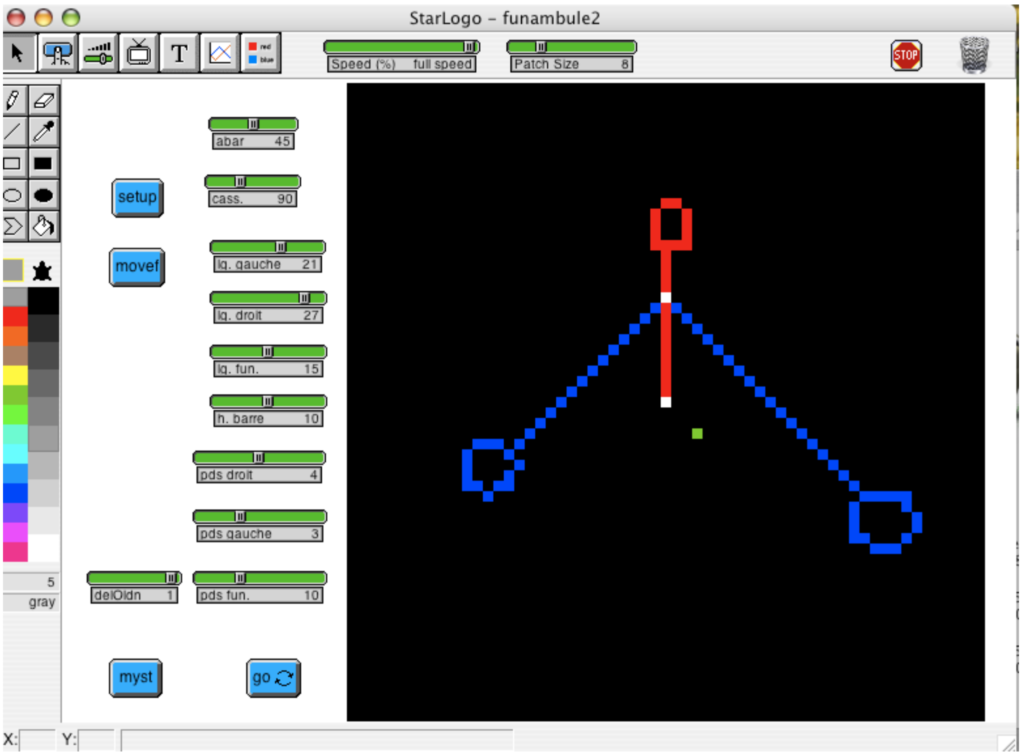


fig 3. Second version of the model

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.

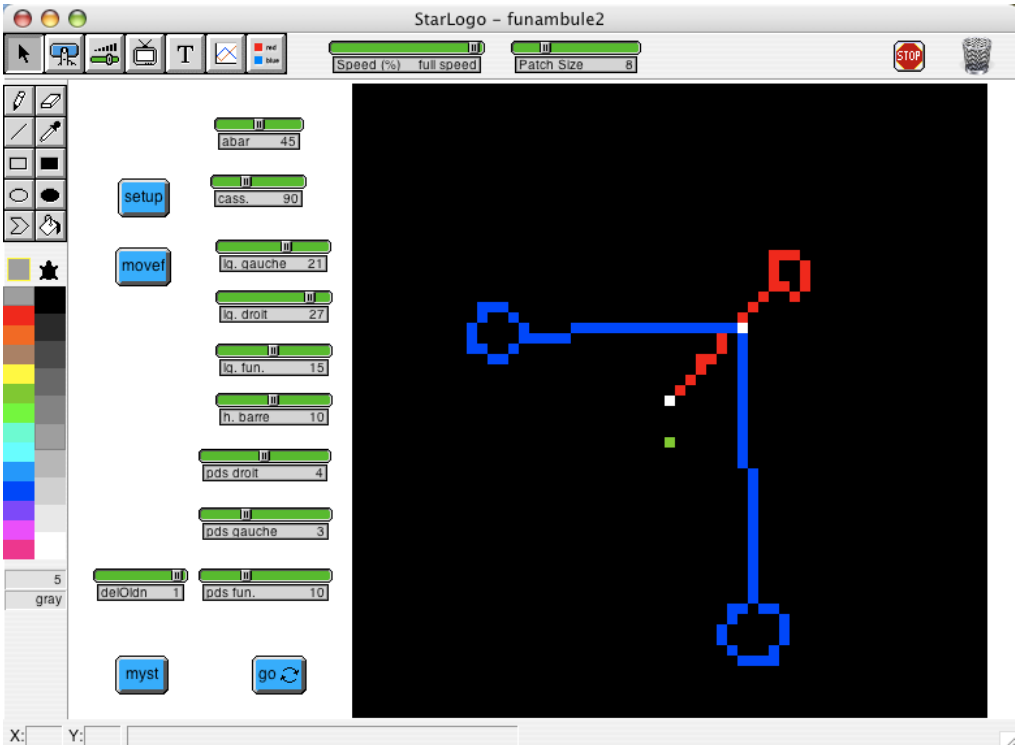


fig 4. In a position of equilibrium

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.

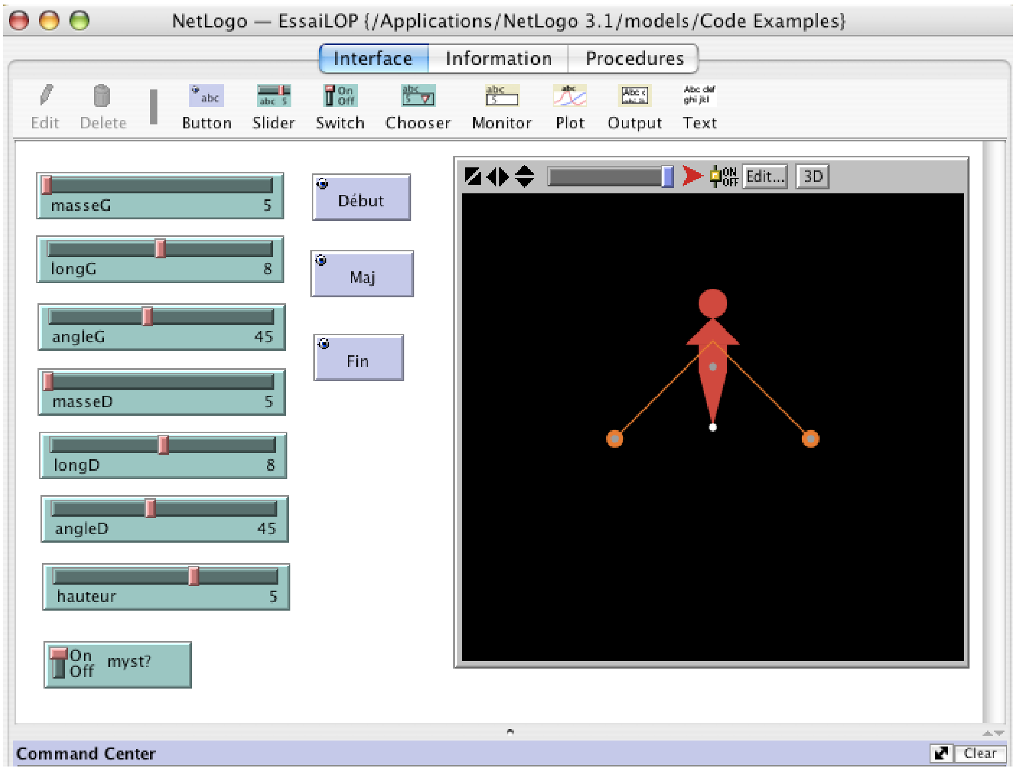


fig 5. After « Début » (= start): The tightrope walker appears with parameters by «default »

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 pole[12] and the rope. The first three parts have a « centre[13] », 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.

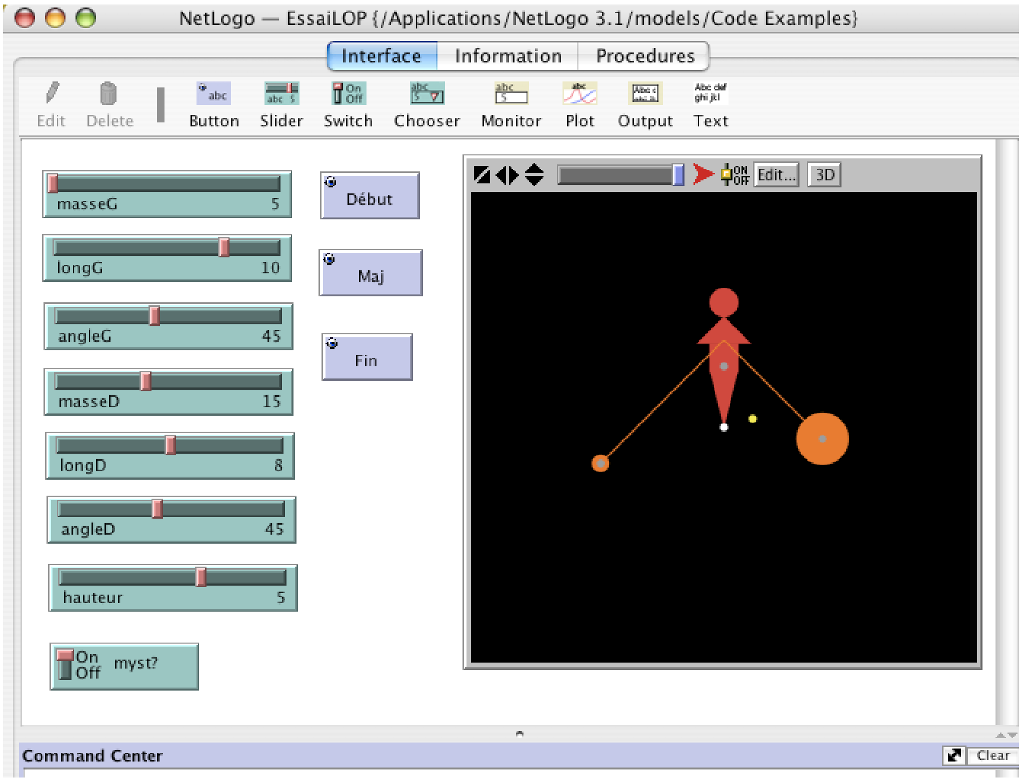


fig 6. After « Maj », the representation is modified according to the parameters.

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.

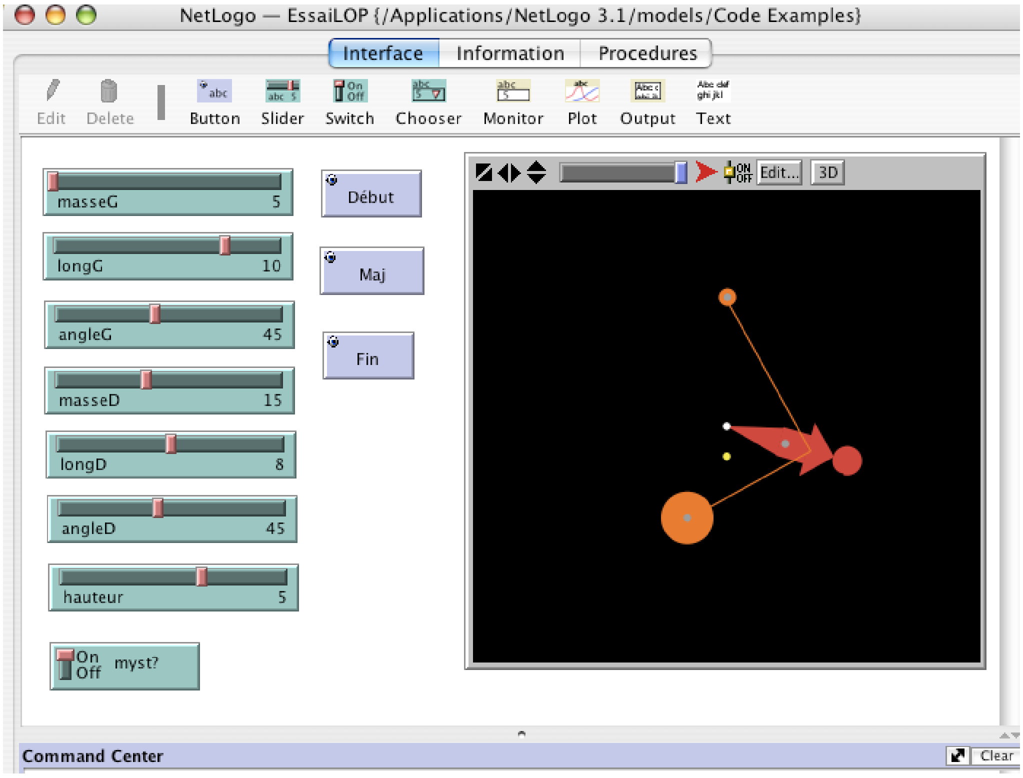


fig 7. After « Fin » (=end), the tightrope walker stands in a position of equilibrium.

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 other[14]). 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.

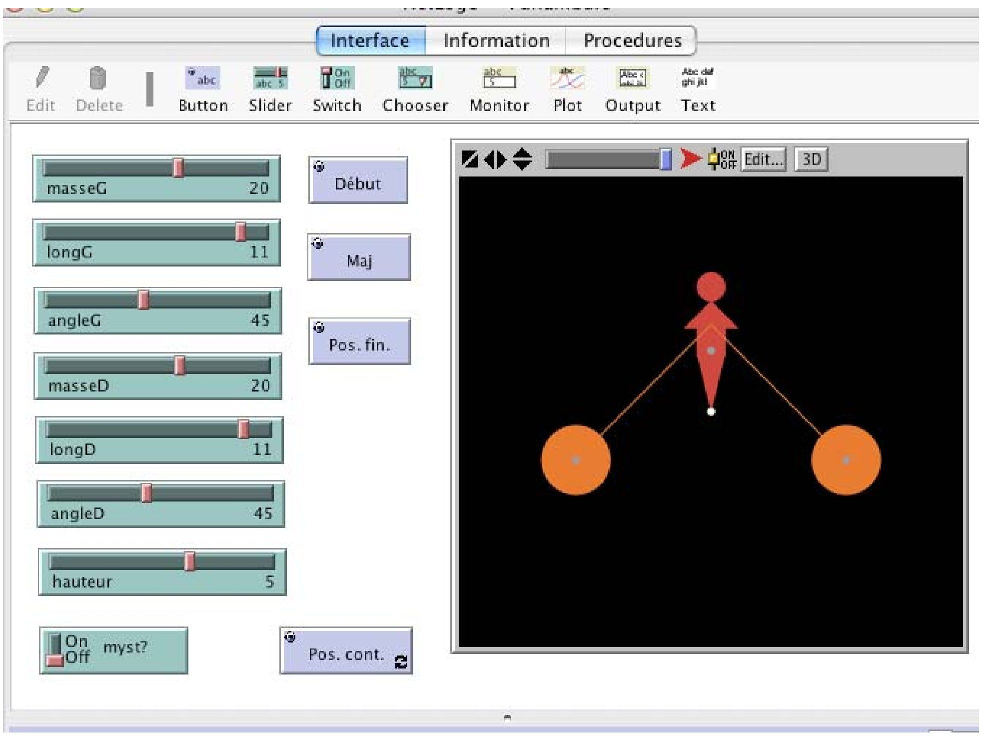


fig 8. With « Pos. Cont. », the tightrope walker changes its position of equilibrium as the parameters are modified

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 report[15]. It was conducted during 5 lessons that were planned from September 2006 to April 2007.

<u>First lesson : Body equilibrium</u>

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

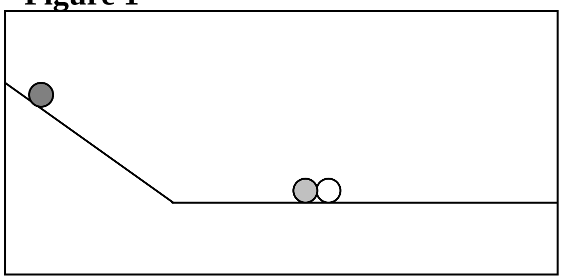
This part of the chapter describes the implementation of the Marbles move case in a secondary school in Switzerland. Implementing an innovative pedagogical practice is known as a complex process with which any aspect of the context is likely to interact (Garduño, 1998). As the project's framework (timelines, 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 adress 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 theirs 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) ½ 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 ½ 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

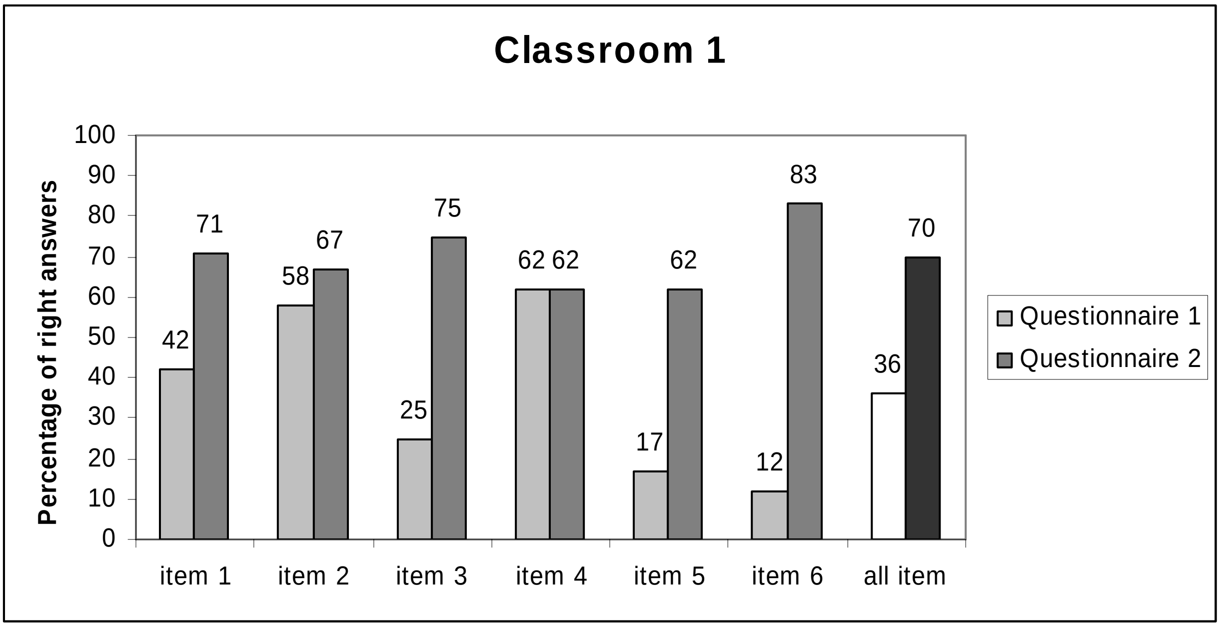
Social interaction and commitment to activities

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.

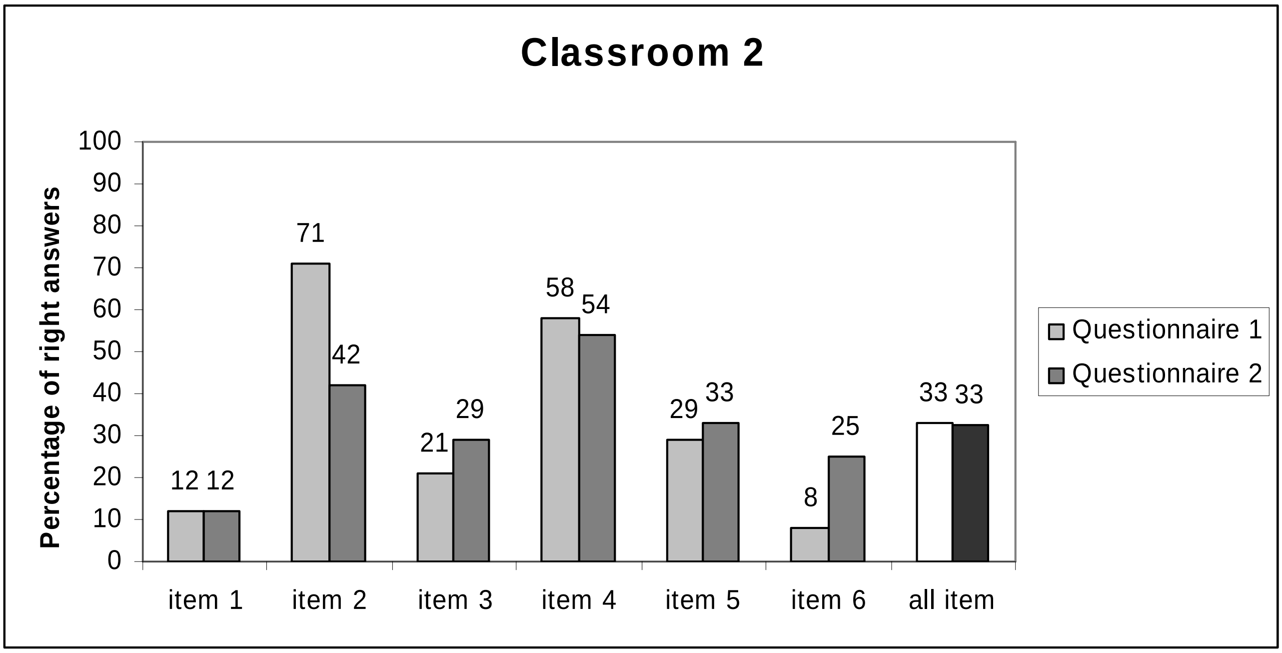
To evaluate the social interaction from the Digalo maps, we observed which kind of resolution strategies occurred when conflicting answers were shared on the map. We found both social resolution of conflicts and social construction of knowledge. The data do not allow us to support the idea that the Digalo 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 $9.81 m/s^2$"). 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 requestioned 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 valuated 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

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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).

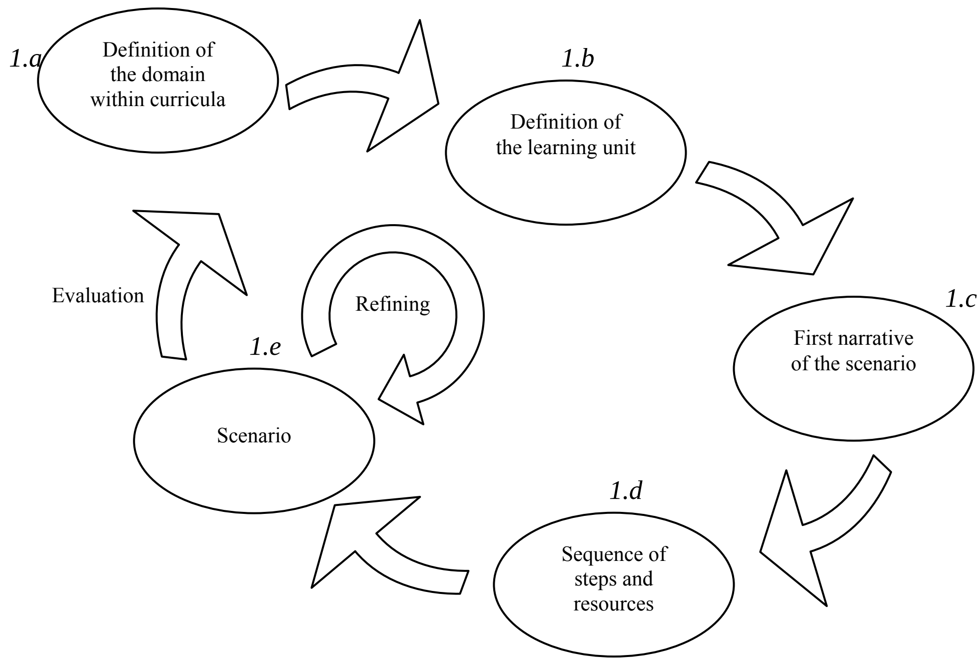
The scenario-based approach is often used in educational research projects as an analysis, design and operating methodology. Nevertheless, it is mainly used analytically, as a tool for capturing teacher and classroom practices, designing new activities and formalising them in CSCL educational situations (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).

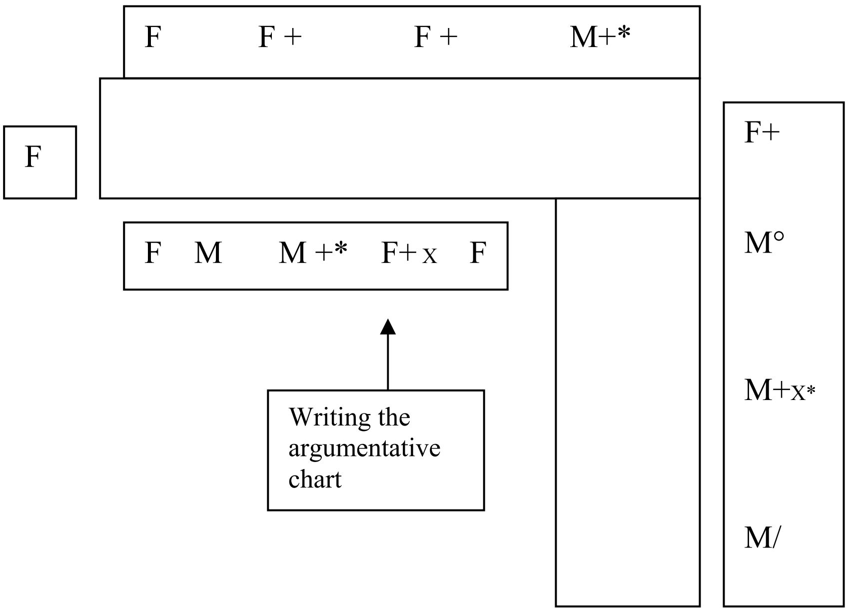
Figure 2: students during the individual study phase

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

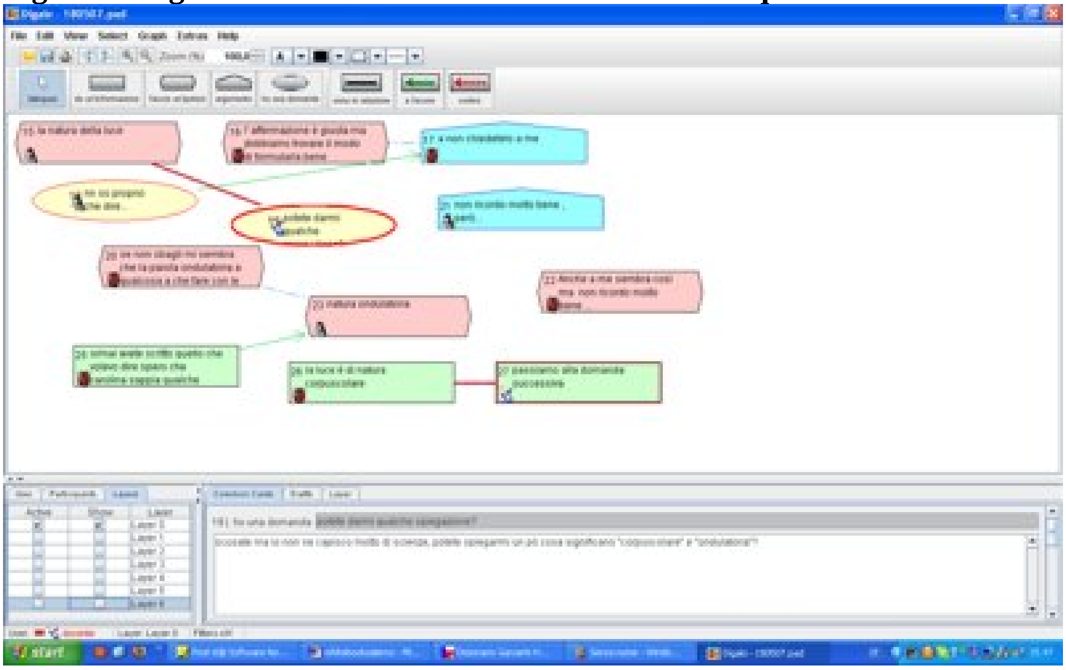
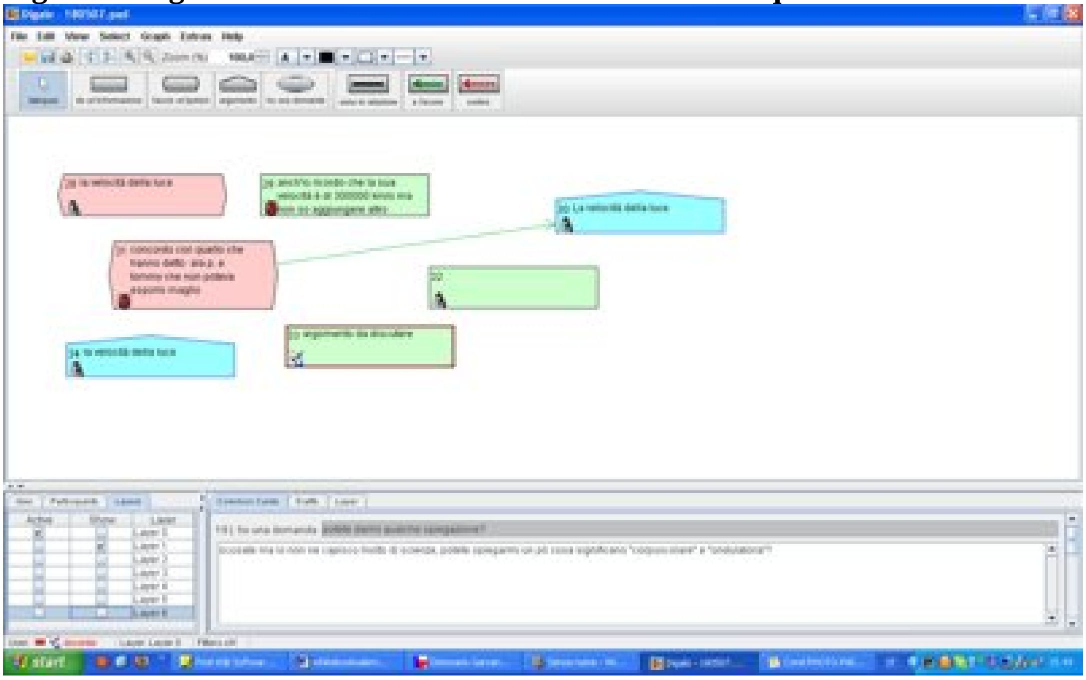


Figure 6: Digalo screenshot of discussion about the 2nd question



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 al 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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ESCALATE: The White Book

Chapter 9: Description of the experimentations in Israel

Sub-chapter 9a: The Argumentation and picture- mediated perspective-taking for learning the day/night cycle: progresses and challenges

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Table of Contents

9a.1 Abstract

The present study focuses on learning the concept of day/night cycle. Like all other studies in the ESCALATE project, it combines two kinds of activities, the first one of an argumentative character, and the second one of an inquiry-based character. Inquiry-based activities are realized through the consideration of multiple perspectives and the mediation of the teacher. Thirty-two Grade 8 students from two junior-high schools participated in the study, which was conducted as a part of regular lessons in Science. The design of the lessons combined the use of Digalo as a graphical tool for representing argumentative moves in on-going e-discussions and inquiry methods through the analysis of a model – here pictures of celestial bodies from different angles, in order to encourage a less egocentric (decentrated) point of view of the concept of day/night cycle. Some of participants received intensive mediation by a tutor (teacher or experimenter) while for others, no human mediation was provided. All students were requested to participate to small groups synchronous e-discussions on the concept of day/night while being presented with different pictures of the moon and the earth. Students' conceptual learning was measured in three manners:

1. We adopted a pre-treatment-post paradigm with pre and post questionnaires. We checked knowledge construction through: (i) Correctness of knowledge – whether students' answers were more correct after the program; (ii) Elaboration – whether answers were more elaborated after the program; (iii) Mental models – whether the mental models of the students improved; (iv) Egocentricity – whether students' view became less egocentric; and (v) whether the answers became simpler, less context-bond.
2. We also examined the effects of mediation on learning through the analysis of discussions in class. Some of the groups received mediation from the teacher, some from the experimenter, and some did not receive any human mediation.
3. We undertook a qualitative analysis of argumentative maps – representations of e-discussions, to identify design principles (e.g., mediation principles) for fostering productive collective argumentation.

It appears that concerning comparison of pre and post tests, all measures of knowledge construction (correctness, elaboration, egocentricity, mental models and simplicity) pointed at improvement (for correctness, significance was not attained, though). It also appears that human mediation in e-discussions did not lead to greater beneficial effects. Analyses of the e-discussions show interesting directions concerning specific vs. generic interventions and differences between the mediation of the experimenter and of the teachers. These results suggest the hopes that argumentative design raise in Science Education, but the challenges concerning the role that the teacher should play in such activities.

9a.2 Argumentation and enquiry activities for concept learning in Science

The project ESCALATE is based on the fact that argumentation is potentially beneficial for learning scientific concepts. As shown in Chapter 3, the Digalo system provides mediation to use certain ontology in e-discussions, and by doing so helps students reflect on the value of their own contributions in co-constructing knowledge. Inquiry-based activities provide procedures that help children in engaging in scientific activities.

However, even in this very rich framework, co-construction of knowledge is very difficult to sustain. Massive human mediation may be crucial for structuring interactions. The series of chapters in this book show that it is difficult to establish generalities: for some scientific concepts, human mediation seems to be superfluous beyond providing graphical argumentative tools and enquiry procedure scripts. In this chapter, we check how junior-high school students learn the concept of day/night cycle, and whether human mediation helps in this endeavor.

The rationale for the choice of the concept of day/night cycle

The day/night cycle was chosen for several reasons. The first is its relevance to the students lives – it is a phenomenon they witness every day. Students have explanatory schemes they use to explain to them or others events linked to the cycle of day and night. Discussing issues on day and night is then not unnatural for students. The second reason is that the development of the day/night cycle concept has been explored in several studies. For example, Trumper (2001) has found that 1/3 of high school students had no satisfactory explanatory frame to explain this cycle on earth (Trumper did not check the understanding of the day/night cycle in celestial bodies in general). Baxter (1989) undertook a developmental study with students whose age ranged from 9 to 16 (only 20 students participated though!). Interviews with these students showed that mental models of the day/night cycle were generally flawed, and even adolescents often had beliefs such as the fact that the sun revolves around the earth during the day and that the moon revolves around the earth during the night. Vosniadou and Brewer (1994) also studied the day/night cycle concept and drew important general lessons on conceptual development in general. First they discerned three stages of conceptual development from naïve models, to synthetic models that integrated naïve and scientific models. More specifically they used three of Kuhn's (1977) five criteria for tracing the development of mental models: precision, coherence and simplicity. Precision expresses the fit between students' explanations and scientific explanations. Simplicity expresses the fact that the mechanisms of explanation are not diverse and context-bounded.

In addition to the familiarity students have with the concept of day/night cycle and the research on this concept, another reason turned it to a good candidate for study. This is the fact that researchers found that some researchers have brought forward reasons for explaining the elaboration of early mental models of the day/night cycle. Several researchers have already suggested that early models of the day/night cycle and of celestial bodies and phenomena in general are influenced by egocentricity (Piaget, 1977; Barnett, Yamagata-Lynch, Keating, Barab, & Hay, 2005; Nussbaum, 1985). Also a pilot study we undertook with university graduate students (described later on) showed that university students may remain egocentric. If egocentricity is central in mental models, a program that focuses on reducing egocentricity may be beneficial. The Thinking Journey pedagogy is exactly dedicated at decentrating students from egocentric views, at observing natural phenomena from different perspectives and by such to break egocentricity. In the next subsection we explain in detail why the adoption of the Thinking Journey pedagogy let us to be optimistic concerning learning the concept of day/night cycle.

Thinking Journey and multiple perspectives
One of the major difficulties in teaching students about astronomic phenomena is the egocentric view children and even adults have about them. For some extent, we are all used to think of astronomical phenomenon in earth perspective, and may find it difficult to think of it from a more universal perspective. The Thinking Journey method is especially designed to overcome problems of egocentricity in science education, by offering multiple perspectives: students are invited to take part to a journey with the help of pedagogical tools such as computerized models, microworlds, or pictures (Schur & Galili, 2007). These tools enable students to see different perspectives, to decentrate themselves. When students are, like in the study described in this chapter, presented with different pictures showing the day and night phenomena in different planets, they are provided evidence that there is more than one way of looking at it, and the integration of these new perspectives are thought to lead to abstraction of scientific concepts.

In general, the journey through different perspectives cannot take place, without a tutor that sustains motivation and points out to differences and apparent contradictions between the perspectives. The mediation of the tutor is intensive; it complies with the principles of mediation articulated by Feuerstein and colleagues (Feuerstein et al., 1980).

Computerized mediation
Like for most of the cases in the ESCALATE project, the Dunes environment was used to provide an electronic medium for sustaining collective argumentation. The HUJI team was aware of the potentialities of Digalo for learning but also to its limitations: conceptual learning cannot generally be attained without human mediation of the discussion itself. Too many dangers lurk in the road of conceptual learning during discussions: agreeing on non-normative arguments, not being critical enough, or simply disengagement are typical characteristics of no-mediated collective argumentation. In a recent study, Asterhan, Schwarz and Gil (submitted) showed that in the case of electronic collective argumentation, most students find computer mediation absolutely necessary. The fact that students find that need is necessary is perhaps linked to the fact that synchronous e-discussions may become so chaotic that students may rapidly loose control on the processes they are engaged in. According to Asterhan and colleagues, students' specific needs are that mediation during the discussion should aim at deepening and maintaining focus, supervising and aiding in technical problems, while not imposing ideas. In this study we examine the mediation types (managerial or content, personal or general, wide or focused) on the amount of student reactions, and their quality (superficial or deep).

9a.3 The social and cultural context of the implementation of the day/night cycle case

In the ESCALATE project, the implementation of cases in schools by the HUJI team is characterized by high sensitiveness to the extent to which designed activities are suitable for specific contexts and by its flexibility for redesign to better adaptation. A pilot study at the university served as a test-bed for trying cases – including to day/night cycle case, and for negotiating cases with teachers, educators and students. For the HUJI team, the implementation is a process whose description is valuable in itself. The presentation of this implementation will be done in different levels of detail. The pilot study is described succinctly; lessons from the pilot study (e.g., for modifying cases) are summarized.

The pilot study

The pilot study was conducted at the end of the 2005-2006 academic year as a final exam, in a class of graduate students regarding the teacher's role in technology rich environments. 11 students participated in the two sessions, arranged in 3 groups of 3-4 students. This was the first of all ESCALATE educational experiments in which tasks in which inquiry and argumentative processes were intertwined and combined with technological tools. Several cases were designed. In a first meeting, students engaged in a first case on the *structure of matter*, so as to prepare themselves to the final session in which an exam consisting in engaging in two cases – the *day and night cycle* and *evolution*, took place. The three designed cases were believed to provide an environment with representational affordances for dialectic discussions, in which displayed evidence could fuel collective argumentation. The case on the concept of day and night was later adapted for the school experiment. Two main questions regarding knowledge construction were studied in the pilot:

1) Did discussants <u>learn from</u> the dialog in further activities? It was tackled by comparing students' answers before and after the designed activities. Students had to give a definition to what day and night are before and after the activity. Two aspects were explored – the correctness of knowledge/compatibility with current scientific consensus, and knowledge arrangement classification – whether the mental model used by students to understand the phenomenon is egocentric, synthetic or universal.
2) The second research question was qualitative in nature and focused on the nature of knowledge construction at it emerges <u>during</u> the dialog.

The teacher first presented the topic and instigated a brainstorming in which some pictures, experiments with microworlds, or "real" experiments were demonstrated by the teacher himself; in this session, the teacher asked for possible explanations for such evidential data. The data showed different perspectives on the same phenomena, and these perspectives uncovered apparent contradictions. The data presented in this session served in successive activities as evidence to be taken into consideration. Then, the teacher organized a small group session of Digalo discussions. One student for each group (3-4 students per group) was asked to serve as moderator to mediate small group discussions. Other students were asked to discuss critically the issue. Finally a reflective teacher-led plenary discussion was held, in which an effort was made to clear out all remaining questions and unresolved issues.

The pilot study showed interesting findings. Concerning the first research question, the activity was beneficial to at least some of the students as they exhibited less misconceptions in the posttest essay than in the pretest essay. All students had 100% accuracy in the posttest. Another interesting finding is that 4 out of 11 students seemed to progress from an egocentric to a synthetic level from the pre-test test to the post-test. These findings pointed to the tangibility of our general hypothesis, the fact that the combination of synchronous e-collective argumentation with inquiry activity with a multiple perspective approach may help students enrich their mental model of the day/night cycle.

Concerning the second research question we undertook a fine-grained analysis of discussions to trace how ideas were adopted, elaborated, challenged, modified or abandoned, in order to create new ideas and concepts. We saw the importance of mediation in invoking some ideas, challenging others, and asking for clarifications and better explanations from student in order to enhance the explicitness of their ideas. We also saw how evidence provided to students was poorly used, and we observed the pronounced preference to use prior knowledge rather than capitalizing on experiments or pictures they just saw.

Rationale for choosing the schools for implementing the day/night cycle case

The day/night cycle case was conducted in two schools in Jerusalem, the "Masorati" school, and the "Gilo" junior-high school. Both schools were highly motivated to participate in the study. The "Masorati" school has a long tradition of innovation and cooperation with academy. The principal ideal strived at integrating new pedagogical techniques and technologies, as well as empowering and promoting teacher by providing them with new and empirically based tools for teaching. In this tradition of innovation, many teachers were eager to participate in scientific adventures aimed for example at improving learning environments tools, or providing students with novel learning experience. The "Masorati" school strives for excellence and its students comply with high level standards. In contrast, the "Gilo" school is committed to social integration. Its population is diverse from different socio-economical backgrounds. Motivation in both schools was also simply motivated by trust between members of the research team and the teachers or principals: the "Masorati" school had collaborated with members from Baruch Schwarz's lab on fostering argumentation in classrooms. All teachers in the current study had a previous acquaintance with Yaron Schur, and with his Thinking Journey model. Yaron is known as a physicist dedicated to science teaching, in particular to teaching concepts in physics. The textbooks for students and the guides for teachers are known for their usefulness for authentic learning in classes, and for providing good advices for mediating students' learning with models.

The recruitment of the teachers

Yaron Schur recruited four teachers. Three of them had previous knowledge in mediating using TJ. They never had any experience in working with a computerized version of TJ and they needed to get acquainted with the use of the combination of a computerized model and TJ mediation connected to it. All four teachers agreed to participate in the project voluntarily, and attended a two day long seminar for their preparation. The seminar is described further on.

The design of the day/night cycle case

The creation of the case was done in several stages. The first draft of the case was based on the pilot study in which an earlier version of the case was implemented. This first draft was then sent to each of the research team group members for comments and suggestions for modifications. For example, we created a pre-post questionnaire for checking students progress (as opposed to a single question in the pilot study) which was more elaborated to allow examining other issues such as the type of mental model and simplicity more accurately. We added another section of discussion in class in order to make sure everyone agree on what can be seen in the pictures/evidence, and generally rethought the need to move from computerized to face to face mediation from time to time, in order to keep track of students' knowledge. We also created a follow up activity that uses a different type of information recourse for multiple perspectives on the day/night – a computerized model of the revolving earth, which contains also the sun and the moon. This activity has not yet been used in a research. The updated version was then used on the teachers in the seminar in which teachers were requested to comment on what needed to be changed (see further on). Some of the changes raised by the teachers were integrated in the final version of the cases.

The preparatory seminar

In order to prepare the teachers to participate in this study, we held an 8 hour training seminar organized in two 4 hour long meetings. The seminar was aimed at: (a) preparing the teachers for their teaching by introducing them to the cases both from an epistemological point of view ('teaching them content') and an pedagogical point of view (negotiating with them how to mediate construction of knowledge); (b) Reevaluating and possibly redesigning the cases - Improving and changing them in light of the comments and functioning of the teachers. The seminar took place in the computer lab in one of the schools. The four teachers attended both meetings. In the first meeting the teachers were introduced to the project goals and to the rationale in using Digalo for learning goals. Then, teachers were invited to engage in the first case in the same way that their students would. At this stage, members of the research team mediated Digalo discussions. They were dedicated at fostering the learning of the day/night cycle. Two of the teachers already taught astronomy in their classes, and played the role of students and tried to use their teaching experience to figure out typical explanations and arguments raised by students in their classes. For the two remaining teachers, the game was quite hypothetical, arguments raised often reflected personal views and through participation, content on the day/light cycle was learned. Naturally, all teachers learned how to use Digalo and during their activities, they wrote down comments. After each part of the case, an oral discussion on questions, remarks and problems teachers had was held among them, an educator/researcher and the two experimenters.

The second meeting of the seminar was dedicated to the second case (containing a computerized model of the day and night cycle) and to teaching the teachers how to mediate while using the Digalo. The teachers were divided into two groups of 3 (two teachers and one observing university student in each group). In each of the discussions held in the second case, the teachers took turns, so that one of them teachers was defined as a 'student-discussant', while the other had to mediate the discussion. Technical support was given by the research team. As in the first meeting, a general oral reflective discussion was held among teachers and the members of the research team after each part of the case. The teachers also received background explanations regarding their forthcoming teaching. They were assured that technical and pedagogical help would be supplied, if requested. As a result of the two meetings of the seminar, in light of the discussion and suggestions of the teachers in the seminar and of the e-discussions with teachers as discussants or as mediators, we redesigned the cases. We list here the main issues the teachers raised:

Teachers complained at first that they had technical difficulties in using Digalo. This complaint gradually disappeared as they engaged more in e-discussions. The teachers believed that students would adapt faster to e-discussions. However, they suggested adding a preparatory activity to introduce students to argumentative norms, for example through choosing proper ontology for each of their interventions. They suggested discussing a social issue for such a preparatory activity. The teachers had concerns about managing the activity while sustaining sufficient motivation and discipline. We explained that each class will receive both technical and pedagogic support, and there was a mutual agreement on the need to articulate desirable rules for discussions. A vivid debate focused on when and how to mediate e-discussions, and when to turn to frontal teaching. Different opinions were raised, some claiming that the students will need more clues and information, while the others claimed that the debriefing should only be done at the end. From this discussion, it appeared that mediation strategies would depend on the teacher pedagogical style and that no single mediation strategy would dominate e-discussions. Rather, we believed that several mediation principles for productive collective argumentation would stem from the experiment. However, teachers were not convinced of the necessity of mediation in synchronous e-discussions. Some teachers considered it as not beneficial, even as a burden.

9a.4 Description of the Research

The research questions

We inquired two research questions:

1) Did the day/night cycle case trigger conceptual learning? This question was tackled according to five aspects:
    a. Correctness of knowledge: Did student's knowledge of the day/night cycle improve?
    b. Elaboration of the answers: Did answers become more elaborate?
    c. Mental model: Did mental models of the day/night cycle progress?
    d. Egocentricity: Did egocentricity in viewing the day/night cycle decrease?
    e. Simplicity: Did answers become simpler and more parsimonious?
2) How does mediation effect students' construction of knowledge through argumentative activities? This question is being tackled according to two aspects:
    a. What was the role of mediation in the group discussions?
    b. Are there actions or patterns of actions for mediating synchronous discussions?

Method

Participants

32 8th grade students from 3 different classes in two schools in Jerusalem: two classes from the "Gilo" school and one class from the "elitist" "Masorati" school. The "Gilo" school is integrative, with students from different socio-economic background; yet, the students in the class are highly motivated and have voluntarily chosen to participate in astronomy classes. All students mastered basic computer tools (Office, internet). The study took place as a part of the regular science classes throughout the school year. Each class (of about 30 students) was divided into two cohorts; each cohort was further divided into groups of 3-4 students. The classroom activities were led by the teachers. As aforementioned, the teachers were all experienced and highly motivated. All of them had already participated in Thinking Journey training activities in the past. Three out of the four teachers had already taught the "Thinking Journey to the Moon" program (Schur, 1998) in their classes. The four teachers attended the seminar described above.

Tools

A questionnaire including knowledge items and questions in which students were requested to explain day and night phenomena. An example of knowledge item is:
"Is the day and night phenomenon unique to the earth?"
An example of explanation requested is:
"How would you explain to a friend the phenomena of day and night?"

The full version of the questionnaire appears in Appendix A.

The second tool consists of the Digalo graphical tool for representing collective argumentation. The third tool is the preliminary task, an e-discussion on a moral dilemma, the moral right to undertake experiments in animals. Before and during the Digalo-mediated collective argumentation, the teacher articulated rules for good discussions such as obligation to provide reasons for advanced claims or to try to challenge arguments when disagreeing or to be sure that the advanced argument is solid.
The fourth tool consists of the case itself. It comprised worksheets and pictures of day and night on the earth and the moon from different perspectives. The full case appears in Appendix B.

Collection and analysis of the data
All questionnaires were collected and argumentative maps were recorded. All lessons were video-taped.

Correctness

The grades for the *correctness* variable ranged from 0-2.
0 – incorrect answer
For example: Q: Are there day and night on the moon?
A: No, there is only night on the moon, because it's dark.
1 – partly correct answer
For example: Q: How would you explain to a friend the day and night phenomena? A: The earth revolves around itself and around the sun. When the earth revolves, and a certain area is not lit, the sun begins to light it, since the earth also revolves around itself. (*The answer is only partly correct since it involves the fact that the earth revolves around the sun, which is not relevant for the day and night cycle*).
2 – Correct answer.
For example: Q: Are there day and night on the sun?
A: No, the sun is the source of "day", and this is why there is no night there. It is always lit, so there is always "day" there, and no "day and night".

For the grades for *elaboration*, we formed a check list of ideas that need to appear in each of the questions to receive a full answer. Each phrase received one point. Each missing or incorrect phrase that was added received zero points. We summed the number of points and divided it with the number of total needed phrases for a full answer + the incorrect phrases given by the student.
For example: Q: Explain in your own words what are day and night
<u>Ideas checklist-</u>
- The sun lights (on the earth)
- Day and night exist in different areas of the same celestial body
- Day = light
- Night = darkness
- The moving from day to night is created by the fact that celestial bodies revolve around themselves.

<u>Mistakes</u>- any other idea (contradictory or irrelevant)
Grades for elaboration will be exemplified further on.

Simplicity

The simplicity of the explanations expressed to what extent explanations for the day/night cycle became more similar when describing the day and night at earth, the moon, mars and other planets. We identified were 4 levels of simplicity translated into grades for simplicity ranging from 0 to 3.

0 – Different answers: a different explanation to the same phenomena for different planets

1 – Non contradictory answers: An explanation to at least one planet and the rest is not contradictory (lack of knowledge, indecision).

2 – Identical explanation for at least two planets: the same explanation for two of three planets (earth, moon, mars).

3 – Identical answers for all of the planets: the same explanation for all planets and a different explanation for the sun.

An example of measure of simplicity will be given further on

Identifying mental models

We analyzed all explanations provided by the students and analyzed their content in order to identify the mental model of the students. We identified six explanatory frames of the day/night and day cycle.

No model

The sun revolves around the planets

At day the earth revolves around the sun and at night around the moon

The earth revolves around the sun

The earth spins, and the sun and moon are in two opposite sides of it

The scientific model

An example on identification of mental model is given further on.

Two judges compared each of the explanations written with the explanatory frames proposed and either recognized one of them or decided that it was impossible to classify the explanation. For most of the explanations, judges recognized a suitable explanatory frame and agreed upon it. Although there was certain variability in the explanatory frames that the students used, it was possible to maintain an agreement between the judges with Cohen kappa of 0.9.

Identifying level of egocentricity

We analyzed all the explanations given by students in their questionnaires to identify something else from mental models or explanatory frames, the way people saw themselves in the day/night cycle, or what we called their level of egocentricity. Six levels could be identified:

(a) Looking only at oneself on earth, without viewing it as a sphere;

(b) Day and night can only happen on earth;

(c) Day and night can only happen in the earth's environment;

(d) Ability to see the phenomenon as happening in distant planets that are similar in a trait (being lit) with no explanation;

(e) Partially understanding the law – there is a theoretical explanation which is not correct/incomplete;

(f) Understanding the law in a scientific manner.

An example of level of egocentricity is given further on.

Example of an analysis of the questionnaire:

To better explain how the analysis took place we bring you an example of questionnaire in which all variables were measured:

Examples of analysis of data:
We bring two examples for analysis of data. The first will be a full analysis of the pretest – in order to demonstrate how to calculate and determine the grades for each variable. The second will be an analysis of the pre and post tests, in order to demonstrate the change in egocentricity and mental model in a single student.

Example 1:
Details of the questionnaire:
1) Q- Define in your own words what are day and night
A- Day is when the sun light the area where the state is, night is when the sun lights another place (area) in the world, so that the sun lights cannot illuminate this area. This happens when earth revolves around itself and around the sun.

Correctness: the grade is 1, since the answer party correct and partly incorrect.

Elaboration:
Phrases checklist-
- The sun lights (on the earth) - V
- Day and night exist in different areas of the same celestial body - V
- Day = light - V
- Night = darkness - V
- The moving from day to night is created by the fact that celestial bodies revolve around themselves - V

Mistake – Linking the day and night phenomena to the fact that the earth revolves around the sun – X
Calculation of the grade –
5 correct answers out of 6 ideas (one incorrect) – 5/6= 83.3%

2) Q- How would you explain to a friend the reason why day and night happen?
A- The earth spins around itself and around the sun. When the earth spins, and a certain area is not lit, the sun begins to light it due to the fact that the earth spins around itself. When the earth spins , the area of the state that was towards the sun (lit) turns with its "back" to the sun, and becomes night instead of day.

Elaboration:
Phrases checklist-
- The sun lights (on the earth) - V
- Day and night exist in different areas of the same celestial body - V
- Day = light - V
- Night = darkness - V
- The moving from day to night is created by the fact that celestial bodies revolve around themselves - V

Mistake – Linking the day and night phenomena to the fact that the earth revolves around the sun. – X
Calculation of the grade –
5 correct answers out of 6 ideas (one incorrect) – 5/6= 83.3%

Correctness: the given grade is 1, since the answer party correct and partly incorrect.

3) Q: Are there day and night in the moon? Explain.
A- The moon revolves around the earth, and the earth around the sun, so when the moon is between the earth (and the sun), it is lit and there's day. When the moon isn't between the earth and the sun but behind the earth, the sun light doesn't reach it and there's night.

Elaboration:
Phrases checklist-
The moon spins around itself - X
Day and night exist on the moon - V
Day = the moon is lit - V
Night = the moon is dark – V
The phenomenon is identical to the one that happens on earth – X
A lack of connecting between day and nigh at earth and on the moon – X
Mistakes – connecting day and night on the moon with eclipses fro the earth – X

Calculation of the grade –
3 correct answers out of 7 ideas – 3/7 = 42%

Correctness: the given grade is 1, since the answer party correct and partly incorrect.

4) Q- Are there day and night on Mars? Explain.
A- If Mars revolves there are day and night, since rays from the sun reach it, and if it doesn't revolve, then there's always day at one place and night in another.

Elaboration:
Phrases checklist-
Mars spins around itself - V
Day and night exist on the Mars - V
Day = Mars is lit - V
Night = Mars is dark – V
The phenomena is identical to the one that happens on earth – V
Mistakes – Since there is an understanding of how the process works and just a lack of information on whether mars spins, we didn't consider it as a mistake.

Calculation of the grade –
5 correct answers out of 5 ideas – 5/5 = 100%

Correctness: the given grade is 2, since the answer correct.

5) Q- Are there day and night on the sun? Explain.
A- There is always day on the sun, since the sun sheds light, which creates day. There's always light on the sun so there's always day.

Elaboration:
Phrases checklist-
- The sun is the source of Day/light - V
- Not saying that the sun spins - V

Calculation of the grade –

2 correct answers out of 2 ideas – 2/2 = 100%

Correctness: the given grade is 2, since the answer correct.

6) Q- Is the day and night phenomena unique to the earth? Explain.
A- No, it exists in any planet that revolves around itself and around the sun.

Elaboration:
Possible correct answers (choose at least one):
- Happens in all planets of the solar system
- Exists in any lace that the sun lights
- Examples for other stars in which day and night exist
- Happens n every planet that spins around itself - V

Mistakes – Linking the day and night phenomena to the fact that planets orbit around the sun - X

Calculation of the grade –
1 correct answers out of 2 ideas – 1/2 = 50%

Correctness: the given grade is 1, since the answer party correct and partly incorrect.

Mental model – The mental model that arises from all of the student's answers is one that links the day and night phenomena to the fact that the earth/planets revolve around the sun. This is why the chosen mental model is the fourth one.
Egocentricity – it seems that the student in the example has a way of explaining the day and moon phenomena in a similar way on the earth and other places (mars, and other planets), and does that with a clear explanation/rule – day and night happens in any planet that revolves around the sun and around themselves. Since there is a rule that is not fully correct but applicable for explaining the phenomena in many settings the chosen egocentricity level is 5.

Simplicity – the student gave the same explanation (planet that revolves around the sun and around themselves) to two of the three planets in the questionnaire – the earth and Mars. The moon received a somewhat different explanation, involving eclipses from the earth as a reason for day and night. This is why the grade for simplicity is 2.

Example 2:
Pretest:
1) Q- Define in your own words what are day and night
A- day is the number of hours in which there is light. Night is the number of hours in which there is no light.

2) Q- How would you explain to a friend the reason why day and night happen?
A- I will explain to my friend that there is day and night, so that the sun and the moon replace their places and orbit around the earth, and half the earth is lit, and the other half is dark.

3) Q: Are there day and night in the moon? Explain.
A- No, since the moon is outside of the earth's range.

4) Q- Are there day and night on Mars? Explain.
A- No, since mars is outside of the earth's range

5) Q- Are there day and night on the sun? Explain.
A- No, because the sun constantly lights, and it is a star that spreads light, so there's no night there.

6) Q- Is the day and night phenomena unique to the earth? Explain.
A- Yes, since the sun and the moon orbit only the earth, and this is why is has night and day.

Mental model – The mental model that arises from all of the student's answers is one in which the sun (and the moon) revolves around the earth, and this is what creates day and night. . This is why the chosen mental model is the second one.

Egocentricity – the student believes that day and night can only happen on earth, and do not happen in other planets. This is why grade for egocentricity is level two.

Posttest:
1) Q- Define in your own words what day and night are.
A- Day – Half of the 24 hour period in which the sun light a certain area. Night - the other half of the 24 hour period in which the sun doesn't light a certain area.

2) Q- How would you explain to a friend the reason why day and night happen?
A- I'll explain that the sun lights the earth so that half the sphere is lit and half is dark, and that the earth spins, so the part that was lit becomes dark.

3) Q: Are there day and night in the moon? Explain.
A- I think there are day and night on the moon, since the sun lights the moon.

4) Q- Are there day and night on Mars? Explain.
A- I think so, the same way there's day and night on the moon.

5) Q- Are there day and night on the sun? Explain.
A- No, the sun is the source of light.

6) Q- Is the day and night phenomena unique to the earth? Explain.
A- No, since we saw in the Digalo that they also exist on the moon and on mars.

Mental model – The mental model that arises from all of the student's answers is the scientific model – day and night are caused by the sun light, they happen at the same time in different parts of the same planets, and happen in planets that are lit by the sun. Also – day and night cycle happens due to the fact that the earth spins around itself.. This is why the chosen mental model is the sixth one.

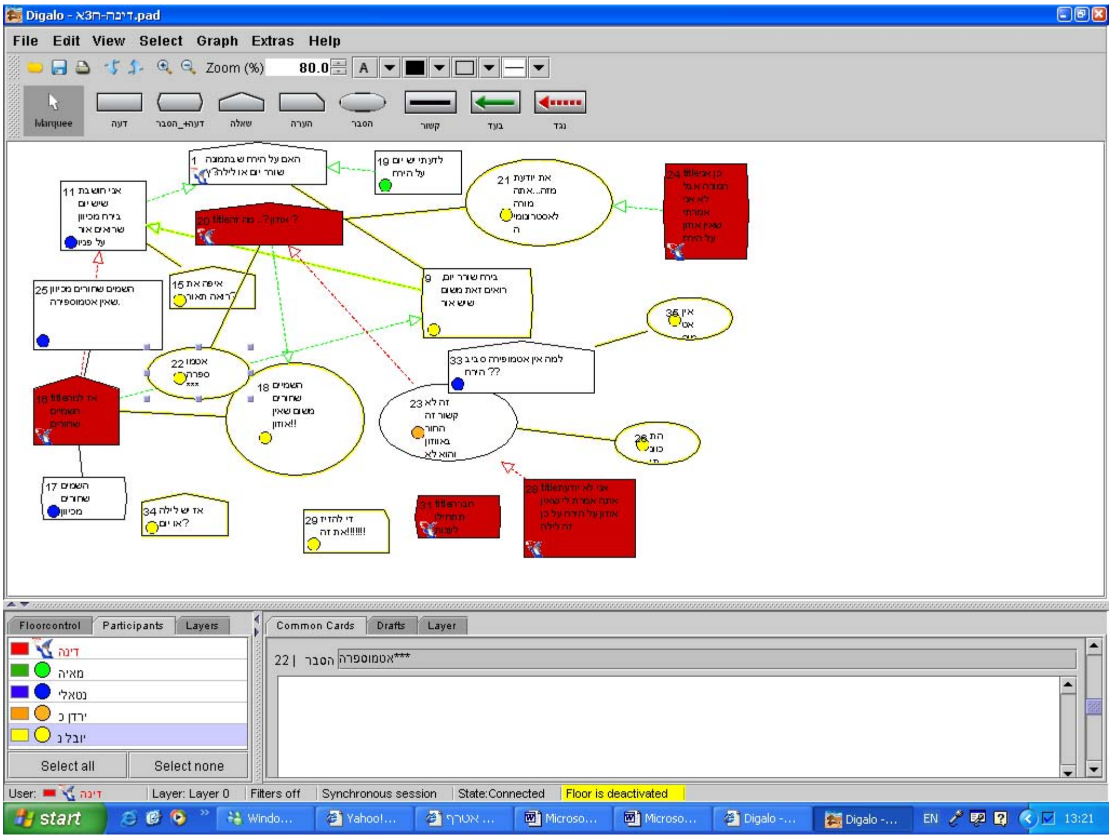
Egocentricity – the student realizes that day and night happen in every planet that the sun sheds light on, and states that they exist on the moon and on earth. There is a rule, and it is correct – the current scientific explanation.

As we can see, this student advanced from an egocentric view that sees day and night as happening only on the earth to seeing it as a universal phenomenon. He also states that he realized it after the Digalo discussion. He also moved from a naïve mental model of the sun revolving around the earth to the scientific model.

Analysis of the discussions

We have examined the influence of the mediation on discussions. Over 180 mediation moves of the teachers and experimenter were gathered and analyzed according to the following parameters:
School: Masorti, Gilo
Mediator: Masorti teacher, Gilo teacher, Experimenter.
Location of contributions in the discussion: Beginning, middle, end
Type of reference: General – to all participants, Personal – to a specific participant.
Type of relatedness: Wide – relating to the wide topic of discussion, focused: relating to a specific point in the discussion.
Number of students to which the mediation move is directed
Quality of students' interventions: Shallow - unserious or irrelevant interventions to the topic, Deep – a serious and related interventions to the topic.
Type of mediation: Content – relates to the topic of discussion, Organizational – relates to aspects such as encouraging students to participate, and a correct implementation of the task.
Frequencies and correlations between the variables were later gathered, especially regarding the influence of mediation on the amount and quality of students' reactions to the mediation moves. The Amount of students reactions was calculated by summing the number of students direct reactions to each of the mediator moves. The other variables were qualitative (such as the type of mediation – organizational or content) and were evaluated by two judges using agreed upon rules (in the case of the mediation type – checking if the mediation move deals with the topic of discussion or with maintaining the discussion). The inter rater variability was high (Kappa = 0.9).

Figure 1 displays an argumentative map with four discussants and one teacher.



In analyzing the properties of the current map, we can see examples of many types of interventions and responses to them. We can see that the first contribution (1) was wide and general and dealt with the content. The students' replies were deep, since they related directly to the question (2, 3). The next step of the moderator (5) was still general and referred to more than one student's answer (Yuval and Natalie), and still in a general subject – why is it dark in the picture. Again it received deep responses from the students (6,7). The next mediation move (9) was more specific and focused on a specific word (Ozone) and received a shallower, and perhaps even a cynical response from the student it was referring to (10). This was followed by another specific and focused mediation move (13), and then an organizational mediation, that is aimed to keen the students focused on the task of answering the main question (18).

9a.5 Results

Since in one of the classes in the Gilo school a lot of data was missing, we decided to combine the results from the two classes together. In order to do that we checked is there are differences in any of the variables between the two Gilo classes. The statistics shows that there were no differences between the classes, in any of the variable. After combining them we are left with two "classes" – one from the Gilo school, and one from the Masorati school.

In order to check whether there were differences between classes before the activity we conducted a MANOVA analysis. There were no differences between the classes prior to the activity in any of the independent variables.

Another MANOVA of 2 (class 1, 2)* 2 (time – before, after) *3 (mediator – none, teacher, experimenter) was conducted in order to confirm the first research question. Results showed an improvement in all dimensions of the first research question following the Thinking Journey activity, except for the correctness of the answers that showed only a tendency towards improvement ($F = 3.61$, $p = 0.068$). Students' answers were more elaborated ($F = 7.85$, $p = 0.009$): students knew more correct details after the activity compared to the situation before the activity. Most students (over 60%) did not hold the scientific model after the activity, a fact which explains why not all answers were correct. Still, there was an improvement in the model ($F = 7.64$, $p = 0.01$), which is a substantial progress in the structure of knowledge that was obtained trough argumentation. There was an increase in the universality of the day and night concepts following the activity ($F = 18.40$, $p < 0.001$) – students could see it as less related to the earth and more general. A correlation between the type of mental model and egocentricity was also found (RPearson = 6.06, $p < 0.001$), so that the less egocentric someone is, the more advanced is his/her mental model. No effect for class or group was found. Finally, students answers became simpler and more parsimony ($F= 4.64$, $p= 0.041$), and they gave closer explanations to the same phenomenon in different contexts.

Concerning the second research question, the type of mediation was found to be in interaction with two of the variables – elaboration ($F = 3.70$, $p = 0.038$) and egocentricity ($F = 5.44$, $p = 0.011$). It appears that there was a greater improvement in those parameters when there was no mediation, or when the experimenter mediated, than when the teacher was the mediator. These findings are surprising, since we would have expected the teachers to help more in students' cognitive gains.

As aforementioned, we also analyzed the mediation moves in the discussion by the following parameters: Mediator, Mediation type (content/organization), Location (beginning/middle/end), Type of approach (general/personal), Type of relating in mediation (wide/specific), Directedness of the teacher, and Quality of interventions of students (deep/ superficial).

The findings show that there was no effect of the location of the mediation on the quality and number of responses it received. Also, all mediators were very active in all parts of the discussions, and their involvement was in many times crucial for the continuation and development of the discussion. The mediation moves that dealt with content (referred to the task) received deeper responses ($F = 22.24$, $p < 0.001$; Beta = 0.405, $p < 0.001$) but fewer responses ($F = 29.66$, $p < 0.001$; Beta = -0.263, $p < 0.001$) as compared to organizational mediation moves. The same is true for a personal approach in mediation, which received deeper responses ($F = 22.24$, $p < 0.001$; Beta = 0.371, $p < 0.001$) but fewer ($F = 22.24$, $p < 0.001$; Beta = -0.495, $p < 0.001$) as compared to a general approach. Finally, wider mediation moves received deeper ($F = 22.24$, $p < 0.001$; Beta = 0.326, $p < 0.001$) and more ($F = 29.66$, $p <0.001$; Beta = -0.432, $p < 0.001$) responses than a specific approach.

UNDERSTANDING THE RESULTS: EXAMINING TWO DISCUSSIONS MEDIATED BY MODERATORS

The results section brought good news, conceptual learning of a scientific concept in an environment integrating argumentation with enquiry-based strategies, but no effect of human moderation. The second findings are quite surprising and explanations are needed. We examined two discussions with human moderation in order to understand what happened. The map of the first discussion was already analyzed (see Fig. 1). In this discussion, there is one moderator who is a teacher, and four discussants, Yuval, Natalie, Maya and Yarden. The map is translated into a protocol in the following. The protocol includes first the subject, then the ontology used (question, explanation, etc), then the text (in italics) and finally the link done.

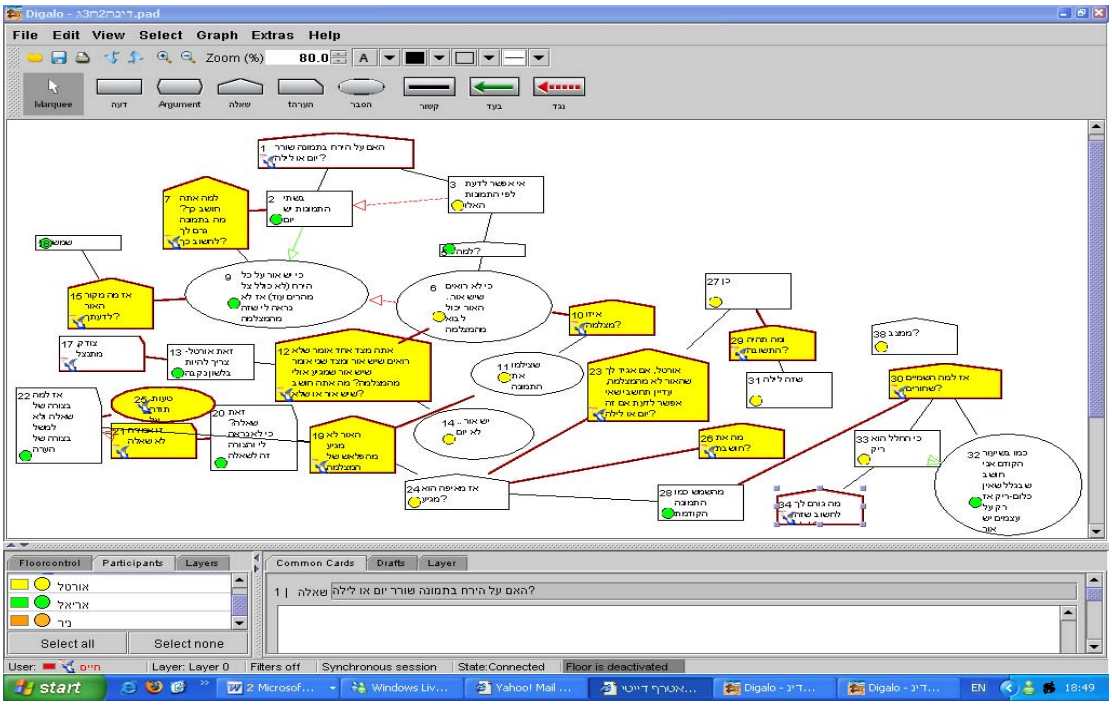
1) Mediator, Question, *is there day or night on the moon in the picture?*
2) Yuval, Explanation, *there's day on the moon. You can see that because there is light* (support to 1)
3) Natalie, Opinion, *I think there is a day on the moon, because we can see light on its surface* (support to 1,)
4) Yuval, Question, *where do you see the light?* (link to 3)
5) Mediator, Question, *why is the sky dark?* (support to 2, object to 3)
6) Natalie, Argument, *the sky is dark because there is space surrounding it, but we see that the moon is lit, no matter what's around it* (link to 5)
7) Yuval, Explanation, *the sky is black because there's no ozone* (link to 5)
8) Maya, Opinion, *I think it is day on the moon* (link to 1)
9) Mediator, Question, *Ozone? What's that?* (support to 7)
10) Yuval, Explanation, *you know what it is, you are an astronomy teacher* (link to 9)
11) Yuval, Explanation, *atmosphere**** (link to 7, 9)
12) Yarden, Explanation, *the hole in the ozone has nothing to do with light in the moon* (object to 9)
13) Mediator Argument, *but I am the teacher, and I didn't say there is no ozone on the moon* (support to 10)
14) Natalie, Opinion, *the sky is dark since there's no atmosphere* (link to 5)
15) Yuval, Explanation, *I meant atmosphere* (link to 13)
16) Mediator, Opinion, *I don't know, you told me there's no ozone on the moon, so it is night* (support to 15)
17) Yuval, Comment, *Stop moving it!*
18) Mediator, Argument, *guys, start answering seriously to the main question*
19) Natalie, Question, *why isn't there atmosphere around the moon?* (link to 15)
20) Yuval, Question, *so, is there night or day?* (link to 18)
21) Yuval, Explanation, *there's no atmosphere because it reaches only* (link to 19)

The first discussion is an example of how mediation can be necessary, complex and sometimes inefficient. (For this group we have full data -both before and after questionnaires, only for Yuval. and indeed it seems that his mental model did not develop, though he became less egocentric). The mediator got mixed in a specific and personal mediation, which did not promote the discussion a lot (getting into an argument about whether ozone explains the fact that the sky is dark on the moon. This discussion took 9 out of 21 contributions, from both the teacher and the students, and did not allow the discussion to proceed. This is especially true since the student corrected himself at the fourth contribution. Ha the teacher be alert to that, she could proceed with the discussion. At the same time she neglected most other participants (giving no mediation to challenge Natalie and Yarden's views who were different than Yuval's), and did not deal with the main issue until it was too late (the 18th out of 21 moves). A good mediator has to deal with a lot of demands: to be alert, organize the discussion, to respond quickly, understand the students' needs and, and scaffold learning. This is why it is not surprising that a lot of the times it is only partly effective.

We present now a second discussion. In this discussion, the mediator was a teacher/experimenter (please choose). Two students, Ortal and Ariel, participated in the discussion. Ariel gained the highest grades for almost all variables even before the activity, and stayed the same after it. Ortal improved on correctness of her responses, egocentricity and mental model(see their argumentative map in Figure 2).

<u>Discussion 2:</u>

1) Mediator, Question, *is there day or night on the moon in the picture*?
2) Ariel Opinion, *there's day in both pictures* (link to 1, support to 7)
3) Ortal, Opinion, *you can't tell from these pictures* (link to 1, object to 2)
4) Ariel, Question, *why*? (link to 3)
5) Ortal, Explanation, *because you can't see that there's light. The light can come from the camera* (link to 3, 4, object to 7)
6) Mediator, Question, *why do you think so? What in the picture made you think so?* (link to 2)
7) Ariel, Explanation, *because there's light on all of the moon, (no including shadows from the mountains) so I don't think it's from the camera* (link to 6)
8) Mediator, Question, *which camera?* (link to 5)
9) Ortal, Explanation, *the one they took the picture with* (link to 8)
10) Mediator, Question, *you say on the one hand that you can't see there's light, but on the other hand, you say that there's light that may be coming from the camera? What do you think, that there's light or not?* (link to 5)
11) Ariel, Opinion, it's Ortal, you addressed her as a male (link to 10)
12) Ortal, Explanation, *there's light, not day* (link to 6)
13) Mediator, Comment, *you're right, sorry* (link to 11)
14) Ariel, Opinion, *the sun* (link to 10)
15) Mediator, Question, the light doesn't come from the camera's flash (link to 9)
16) Ariel, Remark, *is that a question? Because I don't think so, and it's in a form of a question* (link to 15)
17) Mediator, Remark, *it's a remark, not a question* (link to 16)
18) Ariel, Remark, *so why put it as question and not as a remark?* (link to 17)
19) Mediator, Question, *Ortal, if I tell you that the light doesn't come from the camera, will you still think that you can't tell if it's day or night?* (link to 9)
20) Ortal, Question, *so where does it come from?* (link to 18)
21) Mediator, Explanation, a mistake, thanks for the correction (link to 19)
22) Mediator, Question, *what do you think?* (link to 18)
23) Ortal, Opinion, *yes* (link to 19)
24) Ariel, Opinion, *from the sun, like it was in the last picture* (link to 20)
25) Mediator, Question, *and what would be your answer?* (link to 22)
26) Mediator, Question, *so why is the sky dark?* (link to 24)
27) Ortal, Opinion, *'cause it's night* (link to 25)
28) Ariel, Explanation, *as in the last class, I think that since there is nothing, then there's light only on objects* (link to 26)
29) Ortal, Opinion, *since space is empty* (link to 26)
30) Mediator, Question, what makes you think it's night? (link to 27)
31) Mediator, Question, *I ask from each of you to write a final answer, do you think that there's day or night on the moon in the picture, and explain why*
32) Ariel, Opinion, *day – I think since there's nothing-empty, so there's light only on objects* (link to 31)
33) Ortal, Argument, *There's day on the moon, because you see light* (link to 31)



The second discussion shows a different path for mediation. It begins with a presentation of the main question in a broad and general manner (contribution 1), which receives different replies from the students. Ariel claims it is day (contribution 2), while Ortal claims there is no way of telling from he pictures (3). This forces the mediator to move to more focused and personal mediation, in order to challenge each students in its own position. Ariel is being asked to explain and elaborate his response (6), and Ortal is being asked to explain hers – which camera is she referring to (8). In the mean time, the students communicate among themselves (contributions 4, 7). A following interaction on the existence and source of light is raised. The mediator tries to check a possible contradiction in Ortal's claims: on the one hand she says there is no light and on the other hand she speaks of light from the camera (10). Ortal explains she meant that there is light but not day (12). Ariel replies to the question on the source of light, and says to Ortal he doesn't think it comes from a camera (14, 24). The mediator agrees and gives Ortal a piece of information – the fact that the light doesn't come from a camera (19). In parallel, the mediator challenges Ariel's answer that there's day by asking why the sky is dark (26). Both students reply to this question (28,29), and when asked to give their final opinions they both agree that in the picture, there is day on the moon (32,33).
We can see that the moderator accompanies each student through their path of thinking, almost hand in hand in a specific and focused manner, and tries to see exactly where each student stand. He keeps alert to any new idea and comments on it. He does not leave subjects unattended, unless they are addressed by one of the students themselves, and demands participation and reply. It seems that he truly cares about the students and their gains, and invests a lot of efforts in that endeavor.

<u>Guidelines for good mediation:</u>
The analysis of the two discussions shows how different types of mediation are needed in different times and that they raise different responses from the students. Each discussion calls for flexibility from the mediator, a quick understanding of the students' needs and responding to them, as happened in the second discussion, where the mediator reacted

quickly to the students needs, according to their pace. When this type of flexibility is missing, and the mediator responds mostly to one student, as in the first example, the discussion may get stuck. It seems that generally, a good discussion needs to begin with a general and broad presentation of the topic/question, and observing students' replies and condition. In the case of consensus between students (as in example 1), the mediator should continue deepening and elaborating their understanding, and challenge everyone with broad and general mediation contributions. In the case of disagreement (as in example 2), there is no choice but to move to a focused and personal mediation, that forces the mediator to relate and challenge each student separately. Still, a cooperation and discussion between the students themselves should be encouraged, and the mediator should try to support mutual questions and debate between them.
Additionally, when there are difficulties in understanding and operation of the technological tools, problems with discipline, and not enough participation, the mediator should use organizational mediation to promote the discussion.

9a.6 Discussion

The present study has shown that a complex environment based on argumentative and enquiry-based activities can lead to conceptual change in the case of the day/night cycle concept. The research was not designed according to an orthodox experimental setting but rather was quasi-experimental. For example, we did not compare the effects of the use of Digalo to face-to-face discussions. The success of this experiment is in itself very important because it shows the tangibility in the use of complex environments integrating enquiry and argumentation for learning scientific concepts. We lowered egocentricity level by presenting multiple perspectives and discussing them. The visibility of evidence and of discussions could lessen egocentricity level since evidence and collective discussion was made part of the individual's cognitive space. By doing so, students could elaborate superior mental models. And indeed, we found a correlation of r=6.06 between egocentricity and mental model.

In the present research three kinds of moderation were implemented: (1) moderation by a teacher, (2) moderation by an experimenter, (3) without imposed moderator. The findings showed that for three out of the five variables (mental model, correctness and simplicity) no effect of moderation could be detected. Several explanations can be proposed for this surprising result. First, moderation with Digalo is a very complex task. Another completing explanation is that peers moderated each other.

Concerning the complexity of moderation with Digalo, the fact that all previous interventions remain inscribed on the argumentative map, is certainly beneficial for discussants but demands from the moderator to browse a huge amount of information. Another problem concerns the fact that students expect from the teacher to stick to the pace of the discussion (Asterhan, Schwarz & Gil, submitted). In oral discussions, teachers are able to react very quickly but in e-discussions where they have to write their interventions they have difficulties to engage in the e-discussions. In addition, it was very difficult for the teachers to identify their mental models to adapt their teaching actions.

Concerning spontaneous moderation by peers, the fact that the environment invited collaboration, the fact that students felt that they were not supervised invited them to organize themselves. This unexpected finding of spontaneous role taking of organizing synchronous e-discussions is worthwhile further research.

Another surprising result concerns the fact that for egocentricity and completeness, there was an interaction between time and moderation: the improvement was more pronounced within groups without moderation or with the moderation of an experimenter. At a first glance this result is very surprising since the teacher knows her students more than the experimenter, so that she could tailor her teaching actions to her students. We think, however, that the experimenters were much more acquainted with the task and with possible ways to moderate e-discussions. These two facts may explain the superiority of experimenters upon teachers. Also, teachers felt responsible for order in the classroom, so that their attention was less focused on mediating conceptual understanding.

Beyond all types of moderators, it seems that our study suggests several mediations advices whose effectiveness should be checked in further research. First of all, in order to achieve a serious approach the mediator should prefer a mediation that is wide (deals with the larger issues), and relates to the content of the discussion, but directed towards to each of the students. Organizational mediation which deals with maintaining ground rules of critical thinking (encouraging participation, encouraging raising challenges, etc.) may induce more responses, but this kind of mediation may lead to superficial communication. Still, all types of mediation are necessary, since discussions need to be organized, and most of the time the discussion is not purely on topic. The quality of a discussion needs to find balance between content and organizational mediation. Content mediation is crucial for maintaining quality to discussion as it responsible for its depth but integrating this hardcore mediation with organizational mediation is a must: Wider mediations receive deeper and more responses, but the mediator shouldn't stay at this level alone. It is probably preferable for the mediator, as seen in most discussions, to begin with a wider approach, and to move down to the details with more specific questions.

We could not stress enough the importance of the activities with teachers prior the activities in the classes. These activities were not in-service teachers programs aimed at providing new teaching skills but a new approach, a new culture in which science education is seen as a social dialogic activity.

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Appendix A: The pre-post questionnaire (for each question, blanl space was left for answers):

1. Define in your own words what are "Day" and "Night".

2. How would you explain to a friend the day and night phenomena

3. Are there day and night in earth? Explain.

4. Are there day and night on Mars? Explain!

5. Are there day and night on the sun? Explain.
   Is the day and night phenomena unique to earth? Explain.

6. Why does the moon look white? Choose the answer that fits best:

A. Because it's a celestial body that reflects light
B. Because a comet sheds light on it.
C. Because it's close to the sun, which causes fires that light it.
D. Because is it lit by the sun and reflects its light.
E. Other___________________________

7. What do you think causes the day and night cycle?

A. The sun hides behind the mountains.
B. Clouds cover the sun
C. The moon covers the sun
D. The sun revolves around the earth once a day
E. The earth revolves around the sun once a day
F. The earth revolves around its axis once a day

Appendix B: the full case

Concepts of day and night

The first lesson:

Step 1

Questionnaire – will be filled out in class before the beginning of the activity.

Step 2 (15 minutes)

Each student receives two instruction sheets.

The first page is a "zero draft" in which the student is asked to write a short paragraph: "Explain in your own words, what are day and night".

In the second page, the instructions will be: You are an astronaut that has just landed on the moon, and looking towards earth.

- Draw a picture of the earth as it appears from the moon. Display the day and night on earth in the drawing. Point out on the location of day and night in the drawing.
- Write down at the back of the paper questions that arise while drawing

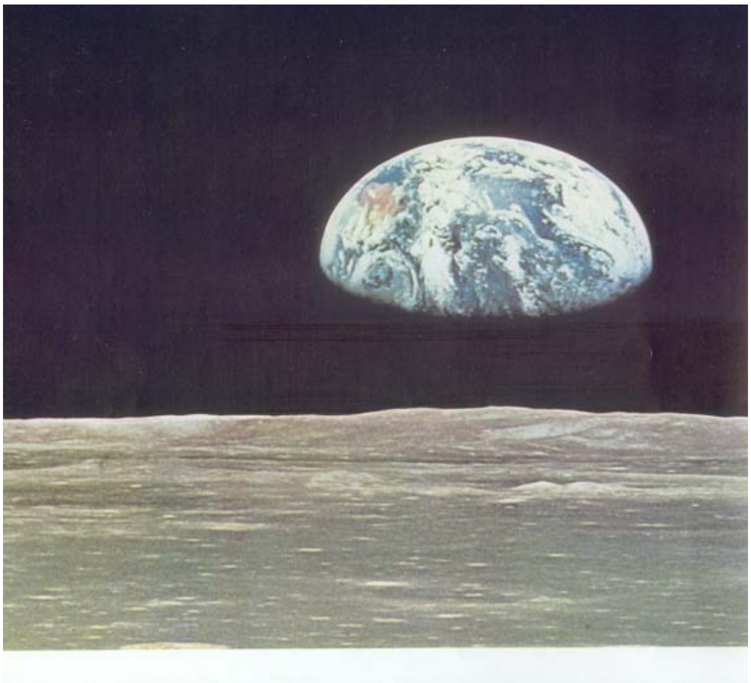
Step 3: Preliminary class discussion (15 minutes)

Student will display their drawings and the questions that rose while painting them.

The teacher will raise the question of what do we see when we look on the earth from the moon to discussion, while relating to the earth's properties (shape, colors, clouds, etc.)

Step 4: First discussion (15 minutes)

Students are divided into predetermined groups (approximately 3 groups, with 3 students in each group). Each group receives a brown envelope, in which there are an instruction sheet, and two pictures that are wrapped in plastic (observations of earth from the moon).



Description of the instruction sheet:

Dr. Daniel Kalahan, manager of the detection department at the National American Space Agency (NASA), entered his office, and got prepared for another routine work day, when he first noticed a brown envelope that captured his eyesight, at the head of his mail pile. The envelope had no recipient on it, but it had a writing in small letters: "Space agency – top secret".

Daniel was so surprised; he forgot all the caution rules and tore up the envelope. A picture fell out of it. Daniel picked up the picture, and curiously examined it. Behind it was a handwritten paragraph:

Dear Dr. Kalahan,

We are in need of your help in an extremely urgent mater. This is a picture that was spotted by our spying satellite for a couple of times the recent week. We would like to figure out exactly what can be seen on it. Awaiting your answer ASAP. One of my crewmembers will contact you.

Obviously, this is a highly classified matter, which you cannot discuss with anyone.

M.

Daniel was curiously mad. He had no idea who this M. person might be. He got back to looking at the picture.

"I better solve this as soon as possible", he thought. What is really shown in that picture?

Enter the Digalo map X. (the maps will be created in advance, with participants' names). Inside the map you will find the question Daniel has to solve

1) What appears in the picture?
2) What is surprising in the picture?
3) How does the picture relate to the drawing you were asked to draw earlier?

Discuss the question as a group, using the Digalo map. Try to formulate a unified opinion.

The second lesson

Step 5 (15 minutes)

After the preliminary discussion phase, when it is obvious that all groups understand what is seen in the picture, each group receives an additional envelope, containing an instruction sheet.

The content of the instruction sheet is:

Daniel was glad, when a tall and seriously looking man entered the office. "You must be waiting for my answer", he said. "And indeed, I already figured out what is going on"…But the man wasn't listening, and only threw a note on the table, and left before Daniel could stop him. The note said:

Dear Dr. Kalahan,

You probably realized that I don't need your answer, and indeed, this question was made only to test your credibility in attending to my matters. Please forgive me for that, you must understand that cautious is necessary in this case. Now that I am certain of your credibility I am ready to ask for your solution for the real problem I have encountered.

I cannot decide whether it is day or night in the moot that's in the picture.

As usual, my man will come for a visit…

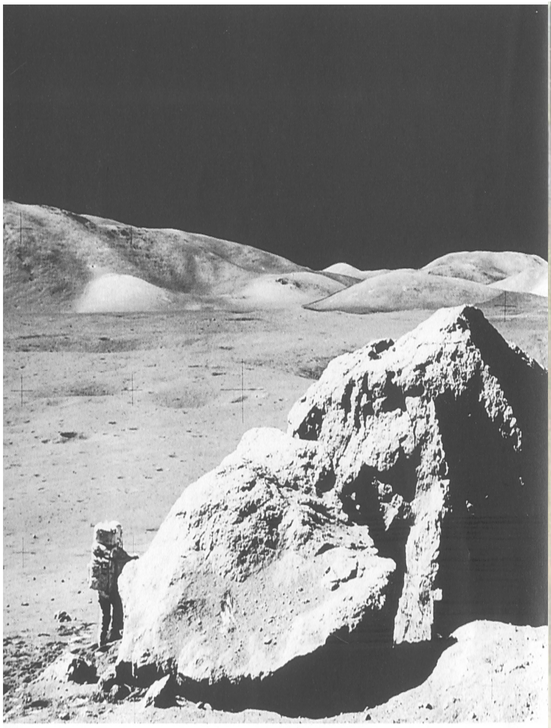
M.

Daniel was a bit upset, but he was still curios. "Indeed a problem", he thought, and got back to looking at the picture.

Return to the Digalo map and scroll down to its lower part. What is our opinion? Again, try to come up with a group decision while discussing the map.

<u>Step 6</u>: additional evidence (20 minutes)

Students will get an additional envelope, containing the two following pictures:




<u>Instruction sheet:</u>

Dr. Kalahan thought he could bury himself, when the tall man came. He barely stuttered: "I'm still not sure… need a little more time… more evidence… that's not enough"…

The tall man gave him one more envelope. "Is this what you wanted?" He asked.
Daniel opened the envelope, and two pictures fell out of it. "More evidence" he sighed in relief. "Thank you!" He raised his eyes, and the tall man was already gone. Daniel wasn't surprised anymore. He went back to his desk, and screened the pictures. "Something here has to help me solve this problem" He thought.

Look at the new evidence as well, and explain what you see in them. Do they strengthen your opinion, or do they make you change it? Get back to your Digalo Map and write down your opinion.

Instructions for good mediation:

1) **To help in the construction of knowledge**
2) **Not to give away the correct answers.**
3) **Try to mediate a "good" discussion.**

Step 4: Working at the assembly (half an hour)

While the groups are discussing the questions, the instructors will map groups or specific students that identify and interpret each of the pictures correctly. While working at the assembly, instructors will address each of the relevant students and ask him/her to explain what can be seen in the picture, and what can we learn from it about day and night.

The teacher will build the following table on the black board and fill it up according to students' answers, while correcting and adjusting answers when it is necessary, and according to the time left for the activity:

Picture no.	**What do we see**	**Conclusions regarding day and night**
2		
4		
18		

Step 5: 10-15 minutes

Write a concluding paragraph (individually):

"Explain in your own words what are day and night"

"What did the activity add to your understanding or knowledge of the topic?"

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Chapter 9: Description of the experimentations in Israel

Sub-chapter 9b: Summarizing report – Argumentation activities using Digalo in the Bloomfield Museum of Science, Jerusalem, September 2006 – April 2007

Y. Orad

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9b.1 Rationale

As part of the ESCALATE project, the Bloomfield Museum of Science in Jerusalem took upon itself to develop and operate argumentative discussion activities in the museum, which will deal with scientific issues.

The activities will allow the museum's visitors, students and wide public, to state their opinion, relate to arguments from other visitors, and elaborate their views regarding the subject matters that come up from the museum's exhibitions.

We believe that the experience of visiting the museum of science offers an elaborate and varied way of learning, in a unique environment, and encourages combining enquiry and experimenting, aside with developing argumentative abilities. The argumentative activity is yet another aspect of the interactive activities in the museum.

Target audience:

1) Students –of junior-high and high school students in the museum, in the school framework.
2) The wide public – Using argumentative dialog activities via the Digalo as an integral part of the activities relating to each of the various exhibitions in the museum, while being tutored.

Goals:

- Students would **express** opinions, views and perceptions regarding to scientific subject matters, constructed by a tutor.
- Visitors would **connect** the phenomena presented in the exhibitions with their scientific principles, while developing a set of arguments.
- Visitors would relate to other visitors' arguments, and consolidate their views following the discussion,

Students

Activity framework:

Target audience: argumentative activities were held in the science museum with **junior-high school students** (8^{th} and 9^{th} grades).

Framework: all activities **as an integral part of a "science encounter"**. Science encounter is a two hour constructed activity of self experiencing in the museum's active environment. Each encounter deals with a specific topic, which is adapted to the students' age, related to the schools' teaching program, or elaborating on it. The subject of activity is usually chosen by the class's science teacher.

Location: The activities took place in the museum's **resource center**, which contains scientific books and computer access.

Instruction and aid: a specially trained **tutor** for argumentative activities would instruct the group for the whole encounter. There was usually another educational team member, and sometimes a "Kishurim" member from the school of education in the Hebrew University as additional aid.

The work on the Digalo was done synchronically, in five different stations.

Materials and equipment: exhibits, accessories and written information, which are relevant to the discussed question.

The encounter: in a science encounter, students are experiencing a variety of different activities, instructed by a tutor, for a group of up to 20 students:

- A guided tour, and operation of the exhibits in the relevant exhibition
- Enquiry workshop in which students check scientific phenomena by themselves
- A scientific example in which the students watch, and participation in a variety if experiments
- An independent tour in the museum
- The argumentative discussion activity, taking place usually at the end of the encounter, as a half an hour supplement, pre-coordinated with the teacher who invited the activity

The course of the argumentative discussion activity (30')

- Gathering in the assembly – introduction, link to the encounter subject and exhibits, presenting the question
- The students are divided into 5 working groups around the computers, and synchronically work on a single shared map
- The students use the exhibits/accessories that are at the center of the room
- Another assembly gathering for the purpose of a final discussion, in which a representative from each group presents, using the map created, the group's point of view, while the tutor summarizes.

9b.2 Pilot activities

At the beginning of the way, several pilot activities were held, after which we particularly learnt how to design the argumentative activities:

- An optimal **duration for an activity**, in the framework of a science encounter is 30 to 40 minutes.
- In order to encourage a discussion between students, **a question** that presents a day to day situation should be presented to them, one which does not have one necessary answer, rather can be related from different aspects that each has clear advantages and disadvantages.
- In order to achieve better involvement from students a question that is relevant to the students' daily life should be presented.
- In order for an argumentative process to occur along with enquiry, one should choose exhibits and accessories that can be checked by the students in the course of the discussion, and not rely only on their memory or prior experience with the museum's exhibits prior to the argumentative activity.

Tutors' seminar

A number of tutors out of the museum's instruction crew were trained for leading the argumentative activity, by watching the students, self-experiencing and discussions about the subject.

Topics for activities

Most if the activities were held as part of a science encounter called "A journey following the light bulb" – an encounter that deals with the operation principles of different kinds of light bulbs and takes place mostly in the exhibit called "In light of electricity". Part of the activities were held as part of a science encounter called "The secrets of communications" – a science encounter that deals with the main stages of the communication process, while focusing in an exhibit that deals with optic communication in the exhibition "What's the connection?"

Here is the list of activities and participants, divided to topics:

List of participants

Science encounter	Groups	Students
Secrets of communication	2	41
A journey following the light bulb	12	166
What hurts? (Experiments in animals)	1	36
Electricity (first pilot)	1	11
Total	16	254

Examples for an activity on the light bulb:
The students experience operating exhibits of incandescent lamp (a regular one and a halogen lamp), discharge light bulbs (florescent) and led light bulbs, and investigate the main differences between the three types of light bulbs in matters of structure, energetic efficiency, and the physical principles which the light discharge is based on, and the color of light. During the enquiry workshop they trace the work of Thomas Edison, searching for a wire that will fit for use in a light bulb.

In the argumentative discussion activity the students are presented with the question:
" A new factory is being built! You must plan the lighting for the factory, that works 24 hours a day non-stop, and the work is done with small and sharp particles. Which type of lighting would you choose? Explain your answers".

9b.3 Feedbacks

Feedbacks from teachers who escorted their students in the activities that included argumentative discussions were generally positive, and some even wanted to continue this type of activity in the school, and contacted the "Kishurim" team.

The feedbacks from students that experienced the activity focused mainly in the technical aspects of the program. They complained that the program is not user-friendly enough, the maps fill out too quickly, and there is a lack of differentiation between the shapes. The students offered to use applications for discussions with multiple participants, which they know from the Internet. Despite these comments, we haven't encountered difficulties in the students' use in the program.

9b.4 What's next?

Several more argumentative activities are planed until the end of 2007 in the museum, as part of science encounters:

- Activities surrounding the topic of light bulbs for Arab speaking students
- Activities surrounding other issues regarding electricity (resistance, flow, conduction and the danger of electrifying) for classes that participate in a special project in which the schools makes preparatory and summarizing activities for the museum encounter ("Magic circle"). In this project, the Digalo will be used as to evaluate the students.
- There may be one activity on the explanation sheet that is attached to medicines surrounding the exhibition "Medicines – health matters!".

9b.5 Evaluation and recommendations

Most activities with students were documented by a representative of the museum's education team and representatives from the "Kishurim" program of the school of education: in writing, video, pictures, and map analysis.

These days we are dealing with a final evaluation of all activities, by the gathered material. So far we see that despite being a one time and not very long activity, the argumentative activity has a unique contribution to the activities for students in the museum of science:

- Increasing students' involvement in the topic of the encounter
- Changing the tutor's role, from one that transfers information to an instructor – the students are the main speakers in the activity. They are given a chance to state their opinions in a non-judgmental manner.
- Giving a chance for participation to students who usually avoid it
- A chance for peer learning. The students relate to each other's opinions
- Cooperative learning
- A chance to construct knowledge – the question encourages the students to integrate former knowledge with what's been tested in the encounter.
- Getting to know the core aspects of scientific work.

We hope that by the end of the project (the end of June) we will have more insights.
In any case, the educational team of the museum hopes to succeed and make the Digalo argumentative discussion activity to a part of the regular science encounter activities for students in the museum.

9b.6 The wide public

Target audience: visitors of the museum in vacations, usually with children.

Framework: two connected computer stations for synchronic work, and above them a screen that shows the Digalo map.

Location: forum, a place designed for resting, while passing between the museum's exhibitions.
Notification: in the event board "today in the museum" there is a reference to a "state your opinion" station.

Guidance and instruction: the station in open only in the presence of a tutor from the museum's instruction team that has been properly trained, or a representative of the "Kishurim" group from the school of education in the Hebrew University.

Equipment: in some cases there is also a bag of articles in the relevant topic.

Documentation: a part of the time that the station was opened was ducomented by video.

9b.7 Contents

An argumentative discussion station operated during the year, mainly in two vacations:
- During the "Hanuka" holiday vacation, in December 2006 – the station was placed next to the "House on Mars" exhibition, and the question presented to the audience was "In the last decade, on of the central issues in space study is the sudsy of Mars. Do you think it is important to land a man on Mars for the purpose of research?"
- During the "Passover" vacation – relating to the new exhibition opened in those days – "Illusions – boggling the mind". The question presented to the audience was "Do you think that visual illusions are an advantage, or do they reflect a defect or fallacy of the perception system?"

9b.8 Evaluation and recommendations

In both cases, each time the station was opened, not many people came to state their opinions, and every time only one map was created.

In most cases, the tutor had to encourage the audience to state their opinion. It did not seem that the visitors needed this opportunity, and they usually used the time in the forum for rest and lunch break.

We should rethink the location of the station, method of operation and the question, in order to attract more people.

Museum of Science web address: http://www.mada.org.il

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Chapter 9: Description of the experimentations in Israel

Sub-chapter 9c: The Activities in Givat Gonen

Y. Orad

Cabbage activity description

Orly Halimi, Givat Gonen school, Friday, 19.1.07, 08:00 – 10:00

Age group: 9^{th} grade.
Number of students on group: 15
Present: 12
Missing: 3

The class began with a short explanation by Orly on the expected activity for the students. Also, Baruch's three students were presented – Jamila, Nabila and Nahida, and myself (Yoam). More so, the international program in which the activity takes place was presented.

Students were divided into three groups (Not frontally, but around tables that connected them to a working surface to each group).

The activity started by presenting the problem – the damage caused by pests and the need to deal with it in some manner.

Orly had divided the groups so that each will present a different claim:

- In favor of chemical extermination
- In favor of biological extermination
- In favor of combined extermination (biological + chemical)

Each of the groups used cards, that Orly prepared in advance, with information aimed to the specific group to justify their claims. The students sat in groups of 5, read the cards, discussed and raised explanations, evidence and justifications for their claims in the group. After that stage, each group was invited to use the Digalo to raise its claims, after I (Yoram) presented a brief (5-7 minutes) explanation on how to use it. Each group worked on one computer, and presented its claim and justifications for it. The groups discussed with one another, answering each other and explained their claims, and also opposed the claims of the other two groups. The Digalo discussion continued for about 15 minutes, and then came the time for the assembly discussion. There was a broad discussion.

All students were involved in learning in all stages – raising justifications and opposing others' claims, and discussed solely the presented subject – pests, extermination and the ways to deal with the damage that pests cause agriculture. The activity was intense. All this, despite the group being defined by Orly as a weak one. A number of students asked for additional explanations during the activity, and these were given by Orly and I.

In the end, an unexpected incidence has happened. One of the students erased all the contributions that were written by all of the participants in this activity.

February, 2007

Cabbage activity description
Nicki Avneri, Givat Gonen school, Thursday, 1.2.2007, 10:00 – 12:00.

Age group: 8th grade
Number of students in group: 17
Present: 15
Missing: 2

In a telephone call I made with Nicki two days prior to the activity, she informed me that since there were switching of groups in the new semester, She remained with the weaker group of the two groups. I replied that I don't mind and there is no problem for the activity to take place as planned.

This class began with a short explanation from Nicki about what is supposed to happen in this actvity. The three students that came with me were presented by me – Renin Nahida and Suham,and . I also presented myself (Yoram). Also, the international program in which the activity takes place was presented by me.

The students were divided into three groups (Not frontally, but around tables that connected them to a working surface to each group).

In the current activity, as opposed to the former on (with Orly) neither the problem nor the need (the problem of the damage caused by the pests and the need to deal with it in some way) were presented at the beginning of the activity. Instead, the students received the pages immediately (after the brief presentation of the program, and of the students and myself). Nicki had divided the groups so that each will present a different claim:

- In favor of chemical extermination
- In favor of biological extermination
- In favor of combined extermination (biological + chemical)

Each of the groups used prepared cards, containing information aimed to the specific group to justify their claims. The students sat in groups of 5, read the cards, discussed and raised explanations, evidence and justifications for their claims in the group. We should note that some of the students were emotionally opposed to presenting a claim that they thought should be different.

After that stage, each group was invited to use the Digalo to raise its claims, after I (Yoram) presented a brief (5-7 minutes) explanation on how to use it. Each group worked on one computer, and presented its claim and justifications for it. The groups discussed with one another, answering each other and explained their claims, and also opposed the claims of the other two groups. The Digalo discussion continued for about 15 minutes, and then came the time for the assembly discussion. There was a broad discussion. The main issues that were raised were written on the blackboard.

During the first part of the activity (the part in which students discussed the claims in the cards) the discussion was very loud and undisciplined. Most students were involved, worked around the subject they have been given and were interested, though not in a stirring way. Some of the students (2-3) were not involved in the discussion, became bored, disturbed the other students, and sometimes there was a need for Nicki to get involved to neutralize them.

Some of the students did not understand what was required, and Nicki had to be involved to clarify what is needed.

I intended to make a double lesson activity (90 minutes with no break), but due to the noise and the disturbance of some of the students, Nicki suggested that we release the students for the break between the classes, which we did.

After the students returned to class, I presented the Digalo (5-7 min) and also asked them not to delete their friends contributions, in order to prevent the incident that happened by mistake in the end of Orly's class (a student deleted all of his friends' contributions).

The students started the activity in the Digalo. As opposed to the first activity, this one was dramatically much more quiet, and especially with more involvement from the students. All students in that stage, with no exceptions, participated in the activity and were involved. Students wrote their contributions in three groups, and had discussion inside the groups also. The involvement and interest in this part surprised me a lot, since it was such a dramatic shift, a thing that neither Nicki, Baruch's students nor I expected. One of the groups had difficulty to stop the Digalo discussion when I announced that the class ended, and I had to urge them several times to stop working on it.

The assembly discussion took 6-8 minutes, and the students raised the ideas discussed in the Digalo. The main ideas were written on the blackboard.

In using the Digalo there seemed to be a technical problem: I evidently wrote the name of the shape that was supposed to be response, as question. I've discovered it and immediately changed it, but the computer refused to accept the change, and so for the whole time of Digalo use, The writing "question" appeared twice – once under the correct shape (question) and also under the shape representing response. Although I've tried to change it.

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Chapter 10: Reflections and Recommendations

B. Schwarz and A-N. Perret-Clermont

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10.1 Observation of implementation in the different sites

Baruch B. Schwarz

The five R&D teams that developed and implemented cases in their five respective countries agreed on a general idea, the integration of enquiry and argumentative practices to foster learning in science. The five teams were even more specific as they also agreed in the use of graphical tools as a way to sustain e-discussions and on the use of microworlds and or other resources providing ways to obtain new evidence in order to support inquiry and feed argumentation. Implementation of theory-based ideas in educational settings is always highly context dependent. However, the diversity of the descriptions of implementations of cases is immense. This diversity has certainly a cultural dimension as will be suggested further on. However, in each of their five countries, the R&D teams implemented cases in different sites and the diversity within these sites is still extremely big. In this situation, giving general recommendations may seem an impossible mission. We suggest on the contrary that general directions emerge from the different chapters from which important lessons can be drawn. We also claim that the high diversity (intra and intercultural) point at a profound societal change in values concerning science, the nature of scientific knowledge and as a matter of fact of science education. Diversity, we suggest, points at change at a motivational-individual level and at resistance to change at the institutional level. The different solutions suggest the first, inevitably instable, solutions that emerge from a strong drive of teachers, researchers, designers and students to get rid of an epistemological burden according to which scientific knowledge originates from authority. We organize this chapter according to the general trends that arise from the different chapters.

Readiness of the institutions to science education through argumentation and enquiry

All R&D teams are engaged in educational programs in their countries. They turned to four kinds of organizations: universities, institutes for teacher training, schools and museums. In general, it appears that the educational system is far from being ready to incorporate argumentative practices and to recognize their added value. From the reports it appears that the readiness of the four countries for learning science through argumentation is not uniform. The United Kingdom and Israel seem quite ready while in other countries the organizations are less disposed to integrate argumentative activities. And indeed, the Ministries of Education in England and in Israel recently recognized officially in-service teachers programs for fostering argumentation in Science. In both countries, the official standards include both argumentative and inquiry skills 'to be acquired' One in-service teachers program in UK has already focused on argumentation in science, and one in-service teachers' program included argumentation as one of its foci. These facts indicate that the educational system is sensitive to the need to teach and learn scientific reasoning and not only to scientific facts. Of course, the educational system simplifies some of the central ideas behind argumentation and enquiry: national standards include terms such as 'argumentative skills' instead of 'argumentation' and 'enquiry skills' instead of 'inquiry processes' since institutions are expert in transforming processes in fixed procedures. This is a very good beginning although the gap between an approach of 'skill acquisition' and programs like ESCALATE that are dedicated to authentic scientific reasoning is still big. Not surprisingly, so far, no official in-service program (at least in Europe) has focused on the way the ESCALATE program was aimed to promote scientific reasoning: through (1) argumentation; (2) enquiry procedures; (3) the use of graphical tools for synchronous discussions, and (4) the use of microworlds. The main reason for the absence of official program that promotes scientific reasoning in its

complexity like with the ESCALATE project, is because practices involved in argumentation and inquiry processes in science cannot be turned to fixed procedures whose acquisition can be easily checked. In conclusion, the educational system in the UK and in Israel seems to be very partly ready to the approach suggested by our project. In France, Greece, and Switzerland, it seems that the readiness of the system is less pronounced. The educational system as a whole is not ready to embrace such a complex endeavor.
It is then natural that R&D teams attempted to introduce themselves in existing pre-service and in-service programs mostly without success (e.g., in Toulouse). The way teachers were finally recruited was through workshops (in the UK and in Israel), through projects in pre-service teachers' programs and through one-to-one interaction with a teacher that the researchers or designers knew personally (Greece, France, Switzerland). Another population with which the team cooperated was (not surprisingly) university students. These students were not exploited by the researchers. On the contrary, the ESCALATE project allowed them to ask theoretical questions on research design (in Greece) or on learning theories (in France). For university students as well as for pre-service students, ESCALATE cases allowed for understanding theoretical ideas.

Interest in the ESCALATE program
In all the occasions ESCALATE was presented to in-service teachers, pre-service teachers or to students, it convinced the audience. After all, this success is not extremely surprising. The main ideas of the ESCALATE project are that: (1) scientific knowledge is constructed by people who interact with each other; (2) this construction is motivated by a need; (3) to be acceptable, constructions are be done according to scientific methods; (4) constructions are meaningful for the participants in scientific activities. These ideas are sound, and if they are illustrated by a demonstration of the implementation of a case, they stress what is missing in "traditional" learning of science in classrooms. However, as shown in the next subsection, this first enthusiasm was often tempered by organizational constraints.

Organizational constraints on the implementation of ESCALATE activities
The organizational constraints on the implementation of ESCALATE activities are multiple. First of all, the curriculum specifies the content domains to be included in the program of study for students from age 5 to 16. The curriculum is quite stiff in England and seems more flexible in Israel. It seems in general more flexible in low grades. The settings in which Escalate has been implemented by the five R&D teams are extremely varied. The situation is even more complicated: in each of the countries, the implementation has been realized in diverse ways. The different chapters that describe the experiments undertaken show several important overall phenomena, beyond the diversity we could observe.

1. All teams report on degree of primary interest of teachers, on the preparation of teachers, and on their actual involvement.
2. Primary interest is always very high. People seem extremely interested. Preparation is feasible but more difficult and actual involvement raises institutional problems. Therefore contacts are often realized at a personal level rather than as a part of a program.
3. The support of teachers in preparing activities and even in their structuring in classes is generally great.
4. The confidence of teachers in their ability to conduct and to animate argumentative activities increases as they persist in their participation in in-service

programs that integrate between activities in classes and meetings with researchers and educators
5. The diversity of tools used to evaluate the different programs is extreme. This diversity originates from a cultural shift concerning epistemology and what is valuable in science.
6. Correctness is still one of the criteria to be taken into account. However, other criteria such as coherence or argumentative level are in place.
7. We think that this diversity reflects a cultural shift in which knowledge is
8. In spite of all the problems and the constraints in the implementation of the program, the different experiments reported evidence the tangibility of the integration of argumentative and enquiry activities with the technological environment provided in Escalate. The program worked in the sense that evidence collected supported the general claim that it helped in the improvement of the scientific activity of the students.

Evaluation of participation to cases that integrate argumentation and enquiry-based practices

The evaluation of ESCALATE activities was a challenging endeavor. Each pedagogical chose the methods that suited more its traditions. The result is a plethora of evaluation methods:

1. Field observations – satisfaction, engagement, collaboration between students, role of the teacher (Rhodes, Neuchatel, London, Jerusalem-museum)
2. Collection of outcomes (explanations, arguments, etc.) by learners (Neuchatel, Lugano, London)
3. Correctness of answers in post-test (as compared to pre-tests) (Jerusalem, Toulouse)
4. Coherence of answers (Toulouse)
5. Structure of arguments in written tests (evidence used, reasons, principles, etc.) (London)
6. Focus discussion groups after implementation (Athens)
7. Evaluation of e-discussions – degree of participation, reference to peers, etc. (London, Toulouse, Jerusalem)
8. Evaluation of change in mental models (Toulouse, Jerusalem)

The variety of evaluation methods does not point at chaos but at the fact that the practices evaluated are new and rich. Two important trends should be noted. First, the evaluation of synchronous discussions appears more feasible than face-to-face discussions contrarily to intuition: Synchronous graphical discussions force students to indicate to whom contributions are directed and in what way (support, opposition, neutral). Also, the DIGALO environment provides an argumentative ontology that invites students to flag the nature of the moves they instigate (question, comment, argument, explanation). Although the congruence of the shapes chosen by students and their content is sometimes problematic and suggests that choices of shapes are often whimsical, it appears that the choices help understanding many of the moves of the students. In addition, the technical facilities provided by DIGALO enable the immediate counting of interventions and by such reference to peers provide precious data on the quality of the discussion.

A second trend concerns the analysis of the structure of arguments. It appeared that teachers were able to recognize reasons, evidence, and claims. In countries such as the UK and Israel, where the ministry of Education calls for fostering argumentation, such evaluating tools provide ways to instill standards through evaluative tools that give clear evidence that the standards are reached.

Technological strengths, potentialities and limits

It appears that our vision concerning the collaboration between technological and pedagogical partners in designing new cases partly succeeded: for the MARBLES, THE FUNAMBULIST and HIT THE BALLOON cases. The fact that these three cases were fully implemented is in itself a very valuable achievement: It was possible to collaborate during a very short span of time to tailor cases for implementation in classrooms. This partial success shows that there is a possibility and that this possibility should be exploited in various countries. Especially at a national level, collaboration between official agencies that cumulatively tailor cases in Science Education is a possible endeavor. However, we also saw that in many of the cases pedagogical teams preferred to use other software or material tools. This preference does not point at a failure of the ESCALATE project, for example in the readiness of technological partners to provide quickly suitable tools for implementing cases. Rather, this preference points at the process that pedagogical partners undergo when presenting the ESCALATE project to educational institutions. This process is always a negotiation. The pedagogical team is always attentive to teachers' and students' needs, so that the choice of a case cannot be done unilaterally by the pedagogical team. After an agreement was reached, the pedagogical partners pondered with the technological partners whether to tailor new tools or to use existing tools. Many times, existing tools were sufficiently good for performing reasonable enquiry based activities.

The role of the teacher

The environment needed to operate cases according to the ESCALATE approach is highly complex. First of all, the teacher needs to coordinate between two activity systems (enquiry and argumentation). These two systems are quite different: enquiry based activities are procedural as students must follow a series of stages (asking a question, hypothesizing, testing, explaining); in contrast argumentation for learning purposes is conceptual, thus not procedural. The coordination between these two systems is then very complicated. In addition, the role of teachers in synchronous discussions is extremely complex: discussions are not linear since students interventions can overlap, and students can often sustain parallel discussions with different discussants. The role of the teacher within synchronous discussions is then extremely complex.

All pedagogical teams were aware of this double complexity, and provided for teachers an adequate preparation phase. However, the findings of some of the pedagogical teams seem to indicate that teachers could only partly overcome complexities. For example, in the day/night cycle, the HUJI team focused on the question of effective teaching during synchronous discussions. They showed that the interventions of teachers in synchronous discussions impaired the quality of the discussions and the subsequent cognitive gains of students in post-tests as compared to the subsequent cognitive gains of students who collaborated without any guidance. However, the HUJI team also showed that experienced educationalists that were intensively trained to moderate synchronous discussions could moderate productive synchronous discussions. The help these educationalists provided was found efficient as compared to collaboration without any guidance. An interesting finding concerns the fact that students expected meditational strategies from the part of the teachers (i.e., that help in the elaboration of ideas) over facilitating/social strategies (i.e., that encourage students to participate and to refer to

each other). Facilitating strategies were acceptable only when teachers combined them with meditational strategies.
Concerning the first complexity, the combination between the two activity systems (enquiry and argumentation) all teachers who implemented cases were supported by the pedagogical teams in designing cases and in providing help in activities. Moreover, the teachers were highly motivated. However, the incorporation of evidence collected in enquiry based activities in e-discussions proved to be extremely complicated. Such an incorporation which represents one bridge between the two systems suggests that the new practices that the project ESCALATE have a great potential but need more efforts for broad dissemination.

The last section of this chapter constitutes an integration of all observations in all the sites. Visits from site to site by the same critical eye made it possible to really compare between implementations and allowed for interesting generalizations.

10.2 An integrative view of the observation of implementation in the different sites: from dream to reality

Sheila Padiglia

The observations of the field showed that, as it frequently appears in a research project, the partners involved had to enter in various and iterative processes of negotiation at different level in order to conduct the activities.

A negotiation between conception and realisation

All along the project, the partners had to face this two points showing that they cannot be considered as two separate moments of the process, there are in a continuous and dialogical relation. The design of the conception has to be materialised in the design of the realisation, which modified the initial design, which leads to a new concretisation.

A negotiation between what is possible and what is wished

As it frequently appears all partners had to review their preliminary objectives during the process and especially once they met the field.
Some had to modify some points, others had to completely review the cases they wanted to study or for example had to target another “population” because of lack of interest or administrative involvement.
The changes happened for various reasons:

1. Sometimes the case didn’t fit the curriculum enough to be implemented (it was then left out or modified (most of time with the teacher in order to fit the curriculm).
2. Sometimes the field itself offered the opportunity to elaborate or implement a specific case (in collaboration with the teacher involved).
3. The opportunity of choosing the scenario elaborated by another country was offered, it happened in one case (the English case *Euglenia* has been “digalised” in Switzerland).
4. Sometimes the teachers that were foreseen changed or the number of persons interested was (for example) overestimated.

Some examples of changes

In France, the first idea was to involve teachers in proposing training days at the IUFM (University Institute of teacher training), but because of lack of interest in science topics, they had to try to find another way to involve teacher. They had then the chance to establish contact with one teacher who was also working in the “cité de l’espace”, it offered a nice opportunity of leading the activities in classrooms and in the museum on topics that were present in the exhibitions.

In Greece the partners had very low space of freedom in involving teachers because of lack of institutional support. Teacher training simply do not exist and has no recognition. One opportunity was then to try to implement a scenario in Rhodes where one of the Greek's partners had a contact who offered the "space of freedom" he needed, another chance was to create a new master course at the university that they could directly rely to the project.

In England the number of teachers expected to be interested in the training was higher that what happened in reality, "only" 4 teachers registered. Nevertheless, this "disappointing" situation offered, on the contrary, a good opportunity for the English partners to better frame the activities of the teachers and be more involved in the implementations. Moreover, their presence in the classrooms seemed to reassure the teachers who feared a little bit the introduction of the ICT and to be overwhelmed ("I was happy that you were there in class with me!", said one teacher in the teacher training day).

To implement a project: different realities behind the same words

<u>What reality hides behind a "community of teachers" and classroom activities?</u>

The project aimed the constitution of a *community of teachers* involved in the implementation of the scenarios. The visits in the various countries offered the opportunity to realise that there are various ways of involving teachers in the project and that it depended a lot of the culture in which the institution was embedded. If the partner was part of an institution in which teacher training was part of the offer, to contact teachers was naturally facilitated. And there is another point: the teachers are more or less free to participate to projects, more or less free to introduce topics in the curriculum, more or less incline to participate to teacher training courses (related to the recognition (if there is one) given by the institutional context to this kind of training).

Some contexts offered a large panel of collaboration's opportunities; some others needed more efforts to find people willing to participate. Some institutions had already a long tradition in teacher training (where in-service teachers were paid or not). This means that if the partner was involved in a long tradition of collaboration with teachers (sometimes museums), the contacts and the constitution of the community was then "facilitated". In other cases, the contacts had to be "invented" or induced, it depended a lot from the good willing of teachers met after presentations of the project or via personal contacts taken with them. And in some other cases, the contacts had to be taken strictly out of the educational system of the country; I mean that the implementation didn't have to interfere in any case with the curriculum and that the presence of the partner was highly felt like an "intrusion". As we have already seen in the Greek example, the partner had to elaborate some strategies to deal with the little freedom they had in the country (for example in constructing a new training course or finding a "neutral field" for the implementation).

Examples in teacher training

Two countries, UK and Israel, were offering teacher training day during our visits. The teachers were all volunteers.

In the UK case, teachers were paid for their participation; the trainers naturally expected then something concrete in return. The training consisted in methodological (introduction of argumentation, of Digalo) and practical parts (use of the program, video analyse of in-class activities…).

In the Israeli case the training, a "thinking journey", focused on the case activities (Night and day cycles for example). In this case, the teachers had the role of students learning to use the case (with microworlds and Digalo), in order to be then able to do the same activities in their own classes.

In both countries the teachers seemed to be very involved, but also feared the same problem, that of not being as good as the pupils in managing ICT. They feared the introduction of Digalo and the situation where pupils could succeed to "hijack" the program. The ICT seemed threaten their usual role of teacher who "owns knowledge".

Examples in the classrooms

All classes had a "typical" frontal teaching, done mostly in a computer room, where students could then sit in front of the computers (alone or in small groups).

Pupils' ability to "enter" in the activities depended a lot on the institutional culture in which they evolved concerning: (1) the theme of argumentation, (2) the use of the ICT (Computer management and Digalo) and (3) the implicit or explicit rules of being "good subjects" of research.

(1) The classes in various countries were more or less used to talk about argumentation. In Israel for example the schools we visited had a long tradition of collaboration with HUJI (ESCALATE was not the first project implemented), they were then used to introduce argumentation in their activities.
It was not the case for example in England or in Switzerland were they had to do an introduction on "what is an argument" and/or "how to model the arguments on Digalo" before of launching the activities.

(2) The same thing for the use of Digalo: in Israel, as the students already knew the tool, they didn't need an introduction to the program, in other countries they did. And a technician was quite almost present in all sessions to be sure to avoid technical problems. Pupils in France were younger, some of them had also problems in managing the computer itself and to type, because they didn't find the letters, which created some "tensions" in the classroom, because the were too slow (in France it was a little bit peculiar, because it was the only country which maintained the "floor control", it means that the students had to wait their turn before of writing their arguments).

(3) The teachers who were already familiar with Digalo, ICT and research (as in Israel) developed some tips in order to avoid « unwilling » behaviours from the pupils. For example, at the beginning of the courses the rules of how to use the program and "how to do good work" were rapidly enounced (such as "Digalo is not MSN", "no personal messages", "you cannot use internet", "you cannot write "bullshits"" etc.). Another "good tip" in Israel has been to choose in each group a "supervisor" who kept an eye on the activities of his own group, this role was taken very seriously by the pupils you were chosen!.

Conclusions of the observations: from dream to reality

The observations showed that it is barely impossible to imagine a scenario independently to the field in which it will be implemented (link to the curriculum, to teachers' interest, to institutional recognition, etc.) and that the good willing of teachers is a main factor of success.

The various processes of negotiation and re-adaptation of scenarios and/or implementations showed that what could be seen as a *"disillusion"* in a fist instance, has offered the opportunity to strength the link between what was wished and what was possible, and furthermore it led to very nice and interesting implementations in each country.

The dreamed project is then at the beginning a good factor of motivation and needs the help from the reality to become feasible. Moreover, now that the project is finished, and that we see what has been done in such a little time span and with few resources, we could say that ESCALATE seems to have become a *dreamed reality*.

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