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MODELLINGSPACE

A space for ideas' expression, modelling and collaboration for the development of imagination, reasoning and learning

School implementation and data analysis

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ABSTRACT

The document refers to research carrying out to analyse the uses the teachers and the students can make with ModellingSpace and to evaluate the benefits for students's learning in several knowledge domains and educational levels. Two types of research are presented : cognitive evaluation in quasi experimental context and case studies in school context. The research questions, the educational context and the survey disposal are presentend. The main results are indicated. The positive aspects and the cognitive and environmental obstacles are revealed as well as the precautions to be taken so that the possibilities offered by the software can truly play a positive role near the pupils. New directions for experimentation with the software are proposed as well as innovative uses in the context of education and formation.

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EXECUTIVE SUMMARY

1.1 Introduction

We start from the consideration that, technology based learning environment exploits only part of the functionalities that the designers of ICTs applications support, for obvious reasons of the limits of pupils cognitive capabilities, especially young pupils. Indeed, in the process of learning, the cognitive treatments (seizure and coding of information, drawing inferences, reasoning, etc.) require the implementation of multiple controls which mobilize the working memory. So, the learner is not very able to manage several tasks if the environment is too complex. It thus proves the necessity to conduct studies permitting to evaluate what the technology based learning environment really offers on the cognitive plane, considering the whole didactic system (pupils, professors and tools).

The goal of the researches presented in this report is to analyse the uses the pupils can make with MODELLINGSPACE and to evaluate the benefits for students's learning in several knowledge domains and educational levels.
During the conception of the software, studies were led in Belgium, France, Greece and Portugal. The researchers endeavored to make echo of the encountered difficulties, which allowed an evolution of the software in the direction of a better adaptation to the users.

The studies have different aims and statutes. Firstly, they are simple tests to improve how the students use the software, in partnership with interested professors. At the same time the possibilities of the software and the situation-problems suggested to the students are evaluated. For this type of experimentation, the tools implemented in MODELLINGSPACE proved to be very useful because they allowed a fast diagnosis of the difficulties encountered by the students. In addition, pilot- studies were led with the aim to test the validity of the projected methods of investigation (cf. D02). Lastly, systematic researches were led, with the aim to answer various questions relating to the use of the software.

The presentation of the systematic researches is privileged in this report.

On the basis of critical analysis of former work concerning the evaluation of the educational softwares (cf. D02) two types of systematic researches were led:

- researches having as objective to account for the cognitive activities of the students using MODELLING SPACE;
- researches having like objective to evaluate the pedagogical interest of using MODELLING SPACE in definite pedagogical contexts, in real actual school conditions.

The report is thus structured in two parts corresponding to these two types of research.

For each research, we give detailed data so that future users of the software can have sufficiently precise information on the students' behaviour. In the case of already published researches, only a summary of the results is presented.

Concerning the first type of research, the observers are always researchers in cognitive psychology or education, whatever the context where the pupils were invited to work with the software. Generally they use their personnal computer with a prototype version: first ModelCreator, then MODELLING SPACE.The role of the researcher is only to question the pupils or to observe them working together. He (or she) does not bring other information, only those planned in the experimental protocol. For the second type of research, they are voluntary teachers who took part in the studies. There it is a question of trying out the software under conditions having an ecological validity. In some cases, the teachers themselves were the subject of investigation. In this last case, very precise information on the material and human environment are given in order to be able to appreciate the observations. It is known indeed that the success of the innovations is conditioned by a multitude of factors as well human as material.

Although these two types of research were undertaken by separated teams, the continual exchange of information and investigation tools between the two teams allowed a synergy and a complementarity testified by the studies presented in this report.

1.2 Cognitive evaluation of the MODELLINGSPACE software

1.2.1 Case studies overview

The formal research focusing on the cognitive evaluation of MODELLINGSPACE was divided in four different case studies:

1. Cognitive strategy to induce relational approach at ten years old (end of primary school), when working on the proportionality. The research try to capture students reasoning during: discovery of entities, discovery of relations, interpretation of simulation failure, interpretation of graphs, and finally model construction.
2. Carrying out physics experiments with MODELLINGSPACE in secondary school (13-15 years old children). The research try to capture students reasoning in two comparative conditions: When the experiments are carried out with the computer and When 'real' experiments are carried out.
3. Comparative approach : MODELLING SPACE versus 'Physics by the image' at lower secondary school and upper secondary school . This case study compares the students reasoning and their ability to solve problems when (a) they work with a known educational software (Physics by Image), and (b) they work with MODELLING SPACE.
4. Construction of a conceptual map in different settings of collaboration – among university students (3rd year of Psychology). The task was to construct a conceptual map starting from the reading of a scientific text.

Table 1. Overview of Cognitive Evaluation cases studies

Educational level	Domain	Cognitive activities	Method	Data	Main result
Primary school (10 years old students) N = 16	Mathematic (proportionality)	**Understanding** **Deduction** **Induction of relations**	Interview and observation of dyads	Verbal transcriptions (video recorded) Models Video recordings	**Facilitation** **Cognitive obstacles**
Secondary schools N =	Physics (inclined plan)	**Experimentation** **Prediction** **Deduction**	Individual guided interviews Comparaison MS/*Physics by image*	Verbal transcriptions (audio recorded)	**Relational treatment is facilitated when experimental activities precedes the use of MS** **MS is more adapted to students than Physics by image**
University N =	Psychology (social interaction)	**Construction of a conceptual map starting from the reading of a text**	Observation of dyads in different collaborative contexts	Verbal interactions (oral and written) Conceptual maps	**Peer interactions are affected by collaborative context.**

1.2.2 Conclusions from Cognitive Evaluation of MODELLINGSPACE technology based environment

A number of studies had as objective to investigate the cognitive activities of the students using ModellingSpace; The main support for these cognitive activities can be attributed mainly to the technology based learning environment, given that students do not work into the system of the class [other groups of students, teacher or even other educational material (e.g. worksheets)]

- Comparison of ModellingSpace with another modelling environment based only on scientific modelling primitives: Interacting with ‘ModellingSpace, even the pupils of lower secondary school were able to carry out the experiment thanks to the visualization of the entities, with the expression of the properties in natural language rather than by letter symbols and with the formalization of the relations by means of graphic codes (of the directed arrows various lengths to translate the importance of the variation).(see unit 3.3.)

- The comparison between the pupils'behavior in the two types of technology based learning environments underlines the need of a comparison and linking between the aspects of reality, their conceptualisation and the symbolic notations of those. Learning, specially in some disciplines (Physics) is based in fact on this type of comparison. It is shown that the representation of entities, properties and relations in a figurative form enables students to use the technology based learning environment in a meaningful way compared to the world of actions, objects and events.

  This type of technology based learning environment thus seems to help pupils with the conceptualisation of the situations. This enables them to be detached from the actions and the perceived events for centring on the relations between analytical characteristics of the situations. The assumption advanced by the designers of this technology based learning environment is that this cognitive treatment of the situations is a possible precursor of a quantitative treatment implying of the expressed physical dimensions in a formal way. This aspect is partially validated by the observations reported in a specific context of the study (experimental activities proceed the work with the educational software). (see unit 3.3.)

- The role and the significance of the animation based object-oriented entities: The simulation through animation – representation of a real object-- seems to play a significant role: at first place, it stresses the students' alternative ideas and it furthers structures the content of vector-concepts like those of velocity and position after a short period. More specifically, these entities (a) highlight the dynamic content of kinematic concepts (in opposition to the static representation of books); and (b) students understood the vectorial aspects of concepts (the sign of velocity, disassociating /differentiating it from the change in velocity value as well as from the position of the moving object in relation to the starting point. (see unit 4.4.1). The case study report presents research results on the effectiveness of a specific category of entities (the object-oriented entities with specific representation of motion variables), to make appear students misconceptions related to specific concepts (position, velocity as vectorial concepts) as well as their appropriateness to make students ideas evolve to the scientific ones.

- The observations related to pupils (12 years old) at the end of the cycle of primary education put forward the fact that the pupils of this level are able to use the ModellingSpace software. The selected entities are correctly interpreted by the pupils. However, the interpretation of simulations reveal obstacles already described in other studies as, for example, the interpretation of the modifications in terms of sequential or topological relations. At this school level it seems that a preliminary work about the signification of relation and simulation is benefit. (see unit 3.2.)

- The results obtained support the hypothesis that ModellingSpace constitutes an appropriate tool to help pupils to understand the transformations of the situations into relational terms. Modelling through ModellingSpace could support students to identify the factors play a role in the phenomenon under study and they can express co-variations among variables, in a most important degree than working with real experiments with objects. (see unit 3.2.)

- Finally, Research results (see case 2) draw attention to the cognitive benefit of the use of the technology based learning environment, if it is preceded by an experimental activity with the relevant objects, and thus specially for young students (see unit 3.2.)

- Comparison of two settings: collaboration side by side (in front of PC) with collaboration through ModellingSpace in a shared workspace, during activities of concept map creation.

  The written exchanges through chat are extremely rich as well by the contents of the exchanges as by the structure of the exchanges. Paradoxically, the exchanges are more successful in the written exchanges than in the oral exchanges where the topic of the exchange often escapes the partner. Written statements (chat) do not respect French standard. The writing is often phonetic and uses the short cuts used in the texto sent by cellular telephone.

  It seems that the strategies employed by students vary according the interactional context. When the partners are together on the same workstation, they make much more actions and speak much. When they are separated, they plan better their activities. But finally, the conceptual maps constructed are nearly equivalent. So, we can consider that the distant context is more favourable to the learning of planning activities and cooperative attitude.

1.3 Case studies in real school environments (Greece, Aegean University)

1.3.1 Overview of Case studies

Seven different case studies were conducted in real school conditions. The identity of these cases studies are briefly presented in the following:

1) Class of a Primary school (12 years old students), working with semiquantitative relations and object-oriented entities.

Learning Activities concerns problems with proportionality (Mathematics).

Main Scientific Concepts involved: time, volume of a liquid in a recipient, flow/flux. Experimental situation with real objects in conjunction with modeling through ModellingSpace, Duration: three sessions of 90 minutes. [3 x 45min].

The case study report presents results on the following:

(a) The possibility of young children to express themselves via ModellingSpace semantics concerning semiquantitative relations, their difficulties in some aspects, & specific points where ModellingSpace could create misconception to children when working during a few number of sessions,

(b) children' evolution on reasoning and expressing relations of proportionality,

(c) children' evolution in using related concepts.

2) Class of a Lower secondary school (14 years old students), working with semiquantitative relations and object-oriented entities.

Learning Activities concerns problems with proportionality (Mathematics).

Scientific Concepts involved: time, volume of a liquid in a recipient, flow/flux.

Experimental situation with real objects in conjunction with modeling through ModellingSpace. Duration: two sessions of 90 minutes. [2 x 45min].

The case study report presents research results on the following:

(a) the possibility of students 14 years old to express themselves via ModellingSpace semantics, & their difficulties in some aspects,

(b) students' evolution on reasoning and expressing relations of proportionality,

(c) students' evolution in using related concepts

3) Class of a Primary school (12 years old students), working (a) with semiquantitative relations and object-oriented entities, & (b) with concept maps.

Learning Activities concerns Chemistry problems related to Solutions.

Main involved concepts: => condensation & dilution of a solution, compounds, homogeneity of a solution).

Combination of real objects' Experimental situation with modeling through ModellingSpace (concept maps- models with semiquantitative relations – concept maps).

Duration: six teaching sessions of 45 minutes [6x 45min].

The Case study report presents research results on the following:

(a) The possibility of young children (12 years old) to be easily familiar with ModellingSpace semantics of concept maps creation and simple aspects of semiquantitative relations (implicating only two variables each time),

(b) the appropriateness of ModellingSpace environment and learning activities to support misconceptions appearance and then the evolution on scientific concepts construction,

(c) the ability of young students to work with concept maps and to progress via the whole set of learning activities related session.

4) Class of a Lower Secondary school (15 years old) working with (a) semiquantitative relations and object oriented entities & (b) quantitative relations.

Learning Activities concerns Physics problems related to Kinematics.

Main involved concepts => position, time, velocity, acceleration.

Familiar problems to be modeled via semiquantitative relations expressions and then quantitative ones.

5) Pilot study focusing on the role of object-oriented entities, their simulation and their effect in learning physics concepts.

The case study report presents research results on the effectiveness of a specific category of entities (the object-oriented entities with specific representation of motion variables), to make appear students misconceptions related to specific concepts (position, velocity as vectorial concepts) as well as their appropriateness to make students ideas evolve to the scientific ones.

6) Global results, from a 12 hours teaching unit, on modeling in physics, using semiquantitative and quantitative relations:

The case study report presents research results on the following:

(A) (a) understanding of representations: table of values and graphs , (b) modeling process, (c) teaching strategies

(B) The contribution of MS environment and worksheets on learning concerning: (a) the construction of a structured network of concepts, (b) the relations among specific concepts, (c) the distinction among independent and dependent variable, (d) the relation of proportionality, (e) the notion of a ‘constant variable’, (f) misconceptions and their evolution related to the concept of velocity, and the concept of position (g) students difficulties when they construct algebraic models.

7) Four Classes of a Lower & Higher Secondary school: Teaching & Learning during synchronous collaborative modelling through ModellingSpace among co-located students.

Unified case studies report taking into account, teaching sessions in four different class, and three different schools:

15 years old students (two classes & teachers in two different schools)

16 years old students in a technical high school

17 years old students in a technical high school

The Learning activities concerned mostly mathematics.

Students were involved in quantitative models, and in the use of these models in order to answer related questions.

Duration: eight teaching sessions: [8x 45 minutes]

The Case studies’ reports present research results on the following:

1. The tools that support teachers for collaborative learning activities implementation and management during (online) and after (offline) the collaboration sessions.

2. The meaning, the quality, and the strategies of synchronous collaborative problem solving through MS for the specific modes of use.

3. The comparison of the modes of use.

4. The motivation of students to work on collaborative modelling activities
5. The students and teachers point of view for the learning value of collocated collaborative problem solving using MS.
6. The study of teachers' interventions and their consequences when they participate/supervise or guide the synchronous collaboration between two students.
7. Students' ideas about models and modelling after ModellingSpace based collaborative activities

1.3.2 Conclusions from Evaluation of ModellingSpace environment (technology based learning environment, learning activities, students' worksheets), in school contexts

1.3.2.1 Conclusions from studies where students work collaborating side by side around the computer

A number of cases studies report are presented that have taken place under conditions having an ecological validity. In these cases, the evaluation of the innovation is conditioned by a multitude of factors human as well technological ones. It is to be noticed that the students' progress over the modeling activities' sessions through the technology based learning environment has to be attributed to the combination of a number of factors: the ModellingSpace environment, the specific learning activities (and their design), the corresponding worksheets, the discussions among groups and the discussions among students' groups and teacher, the teachers' strategies and not only to the technology based learning environment itself.

Case studies in schools, involve: semiquantitative relations, qualitative concept maps, quantitative relations, different kind of entities. These case studies have taken place mainly in the frame of : mathematics courses, science physics courses. Students participating were mostly (a) at the age of (11-12 years old), and (b) at the age of 14-15 years old.

⇨ ***Can Young students (e.g. 12 years old) express themselves with "semiquantitative relations"? Interaction with MS, could support them in the learning process ?:***

Young students can express themselves through semiquantitative relations. But, it is to be taken into account that this issue, it is not the unique & central issue in order to work on modelling activities with MS. Additionaly, the topics that students were involved to discuss and they were able to contribute to these discussions were the following:

- The factors that influence the phenomenon and the distinction among them

- Students can express themselves, in terms of intuitive concepts: The most significant is that students progress over the sessions on: concepts construction (concepts that are implicated by each phenomenon under study), verbalization and distinction among them. This is a significant step over scientific concepts' construction & learning. In almost all the groups, we can infer an evolution, on:

  (a) problem analysis (clarifying the central question of the problem),

  (b) intervening factors' identification,

  (c) concepts use, concepts verbalisation ,

From all the studies is revealed, that in all the cases, the most important significant and clear cognitive gain is in terms of conceptualization and scientific concepts construction and learning.

⇨ ***What are young students' difficulties during interaction with MS involving semiquantitative relations ?***

All the students of 12 years old had difficulties on the following:

(1.) To conclude about relations, when the simulation of entities is not produced or when simulation's behavior is not interpreted well. The eventual incapacity to interpret the simulation's behavior leads to ad hoc uses of various variables (and/or entities), relations, and values of variables.

In some cases, children had to observe and regulate the algebraic values of each variable, in order to examine the compatibility among the values of variables, so as the expected simulation to be produced. It is not easy for so young students, to reason in a semiquantitative way (in terms of relations), and in the same time to have to think in a strong quantitative way, in order to make appear the simulation.

(2.) The difficulty to understand the meaning of the constant of a proportional relation among two variables, and its correspondence with the physical status of this constant: a third concept that must be linked with a specific manner (e.g. the flow of tap is the constant into the relation of the proportionality between time and volume of the water into the recipient. Students must link this variable to the relation of proportionality. This indication does not correspond to a natural way of thinking for children).

(3.) The distinction between Independent and dependent variable. The discussion on this distinction has to be continued with a number of examples during a range of different learning activities.

For some groups was easier to cope with these difficulties, while for some others was harder.Students of 14-15 years old have similar difficulties, but they can cope with them easier.

The difficulties are less for students 12 years old, during semiquantitative models creation, when :

(a) the distinction between independent and dependent variables was obvious in this case, given that it was directly related to students' causal actions during real object experiments,

(b) the relation of proportionality implicate only two variables and not three ones (there is not a third variable corresponding to the 'constant' of the relation),

(c) the available object oriented entities that may be linked into models, have compatible values (prescribed by the designers of these entities). In this case students has not to be involved in this reasoning aspect of clear quantitative nature.

In all the cases, it has to be noted that even if some students had important difficulties, in the beginning, they have not lost their interest and their motivation to continue work with MS. Almost all of them seem very motivated to continue the activities with MS. The most significant is that students recognise that they have learned something specific, and they have the awareness of some of them (they are able to mention them).

⇨ ***ModellingSpace support students when they work with qualitative relations, creating Concept maps?***

Students 12 years old, progress in concept maps creations, (the depth of the concepts connections shows an important increase in the final maps, thus students seems to achieve better organization and hierarchy of the meanings). As far as the map structure of the concept maps is concerned, this structure were improved and evolved in more complex and complete forms.

When students work with concept maps, have not difficulties due to the ModellingSpace environment itself.

⇨ ***ModellingSpace support students when they work with quantitative relations, forming algebraic equations?***

Students 14-15 years old, reveal interesting conceptual difficulties when they start to express algebraic equations. The learning progress during quantitative models creation seems to be learning significant.

1.3.2.2 Conclusions from studies where students work collaborating side by side around the computer- synchronous Collaboration through ModellingSpace, involving students collocated into the same class

(A) The meaning, the quality and the strategies of synchronous collaborative problem solving through MS, among collocated participants

Students' motivation in collaborative settings

According to the research data students are highly motivated to use ModellingSpace in collocated learning activities since they are engaged for long time periods in productive problem solving. Students can easily communicate using ModellingSpace means in most modes of use but they face difficulties to formulate a total group in case of OMR (two students in front of a pc collaborating to another similar group with the presence of a researcher per group mode of use).

Teachers' point of view

Teachers' point of view about collaboration among collocated students is positive since: (a) students are motivated, something that is proved according to their opinion by the inexistence of off-task messages and students' positive attitude, (b) unlike to face-to-face collaboration students' dialogues and actions are available.

Additionally, teachers notice that if they design the appropriate activities, this approach can be applied as an alternative way of teaching, for diagnose students' concepts and misunderstandings.

The analysis showed that computer supported collaborative learning provides the teacher with some new opportunities, in spite of certain difficulties (such as time consumption). This is so because learners interact through messages, and this information is available to the teacher as a resource that can be used to assess the learning that has taken place. Additionally, a teacher can monitor the actions at the shared workspace and the dialogues, during problem-solving, and thus can elucidate students' puzzling behaviour. Besides, making the learning process of a group explicit, the teacher can be aware of the students weak and strong points, misconceptions and difficulties and thus be able to intervene and monitor the group more effectively using different strategies according to the situation. Diagnosis is a really hard activity for teachers, and if they have the opportunity to apply it, at least to a certain degree, we consider it is significant both for teaching and learning.

The quality of interaction and collaboration in three different collaborative settings

Conclusions about OME mode of use (two students supervised by teacher): Students are able to collaborate and initiate despite the presence of the teacher. Students ask for the teacher to help them whenever they need so. Teacher need to adapt himself to a new role in which he/she facilitates the collaboration and the negotiation instead of providing the knowledge as the only authority.

Conclusions about OXE mode of use (two students collaborating unsupervised via MS): Despite the absence of adult's supervision students stay engaged in collaboration through ModellingSpace until they solve the activity sheet problems. This is a strong evidence of student's motivation. Students need guidance in order to develop auditing and planning project management abilities. Students are less competitive without adult's participation.

Conclusions about OMR mode of use (two students in front of a pc collaborating to another similar group with the presence of a researcher per group): Despite the quite good use of ModellingSpace and the high motivation of the students the presence of the researcher and the possibility to have face to face communication results at lower quality collaboration in OMR mode. Students in front of a pc preferred face to face collaboration than to the subgroup in the other end of the line. In addition students gave to the researcher a typical teacher role as the performance evaluator and the knowledge authority and they decreased their possibilities to exploit real social negotiation.

Settings comparison: Students were highly motivated in all the modes of use and the quality of the collaboration was satisfactory. In the OMR mode of use the presence of the researcher affected the students and they did not preferred to collaborate online. The comparison of modes of use does not lead easily in true/false result since all the modes of use have their potentials. A very useful result of the study concerning the modes of use is that ModellingSpace can be used as a mirror for the agents in order to become conscious of their learning/teaching styles.

Teachers interventions

The conclusion that we derived is that application was possible and that it had positive effects on teachers' strategies. Maybe teachers face the whole approach positively, in contrast with findings of other researches (Lipponen, 1999), because synchronous computer supported collaborative learning was an integrated part of the learning environment. So, we consider that the use of a networked environment for collaborative problem solving with co-present students, was legitimated. Eventually, this approach could be considered as a first step for teachers to explore more powerful approaches that the computer supported collaborative learning inspire.

Moreover, such approaches, which are not far away from current teachers practices are often considered as a first step for teachers' involvement to new educational practices with technologies

Students points of view

As far as the students' opinion is concerned students believe that this approach gives possibilities for better collaboration and communication and helps them to develop the ability of expression of their thoughts. Students' motivation is expressed through their willing to participate again in collaborative activities using ModellingSpace.

The above analysis showed that most of the students want teachers to intervene when students ask for it, unlike what happened during our sessions, where as we saw, most of the interventions were teacher-requested.

(B) Synchronous Collaborative Modelling Process through ModellingSpace, and Learning on Modelling.

Students' Answers to specific questionnaires (pre & post activity questionnaires) show us, that students have profit from synchronous collaborative activity, in the learning process related to modeling process, models' status, and kind of models. Modeling is a basic scientific activity and students that are conscious of model concept are approaching science from a better point of view. ModellingSpace can be used for the clarification of scientific modeling for problem solving producing multiple learning advantages for students.

Most of students becomes able to formulate realistic and appropriate ideas about (a) models uses, (b) models 'components', (c) modeling phases, (d) when a model can be considered as 'correct'.

(IV) Teachers evaluation of Interaction and Collaboration Analysis Tools

During the study teachers used the available collaboration analysis tools of ModellingSpace and in addition some more tools have been designed according to teachers' requirements.

Statistics: Most of the teachers believe that this is a useful tool, During using *Statistics* teachers observe mostly key's possession and number of messages per participant for comparison among collaborative members and for their own assessment (when a teacher intervenes during collaboration between two students).

Playback: All teachers mentioned that *Playback* seems to be a useful tool, but they find that it is not so easy to use and most important it is time consuming. Teachers sometimes use Playback in order to do demonstration to students.

CAF: Teachers' global point of view about CAF points out mainly its usefulness considering it as a tool presenting an overview, from which they can derive qualitative information. So by using CAF teachers are able to diagnose collaboration quality or cognitive problems, plan their own interventions and assess students' contributions or theirs interventions.

COPRET: Teachers' global point of view about COPRET points out mainly its usefulness considering it as a tool presenting details from dialogues and actions during collaborative problem-solving, and its justification since teachers can localize students' weak points and detect misconceptions, studying students' behavior and contribution, criticizing their owns interventions and analyzing interventions' results. During using *COPRET* teachers are able to observe details from dialogues between participants and actions at the shared workspace. So teachers become able to identify specific cognitive difficulties as well as eventual misconceptions. Additionally teachers can assess their own interventions and regulate their behavior after studying the results of each intervention they did.

2 INTRODUCTION

The design of tools for teaching using new communication and information technologies (ICTs) contributes to the modification of the contexts of "teaching and learning " (Vosniadou et al., 1994). Indeed, while seeking to exploit the functionalities of the ICTs (diversification of information sources - written, visual and auditory, multiplicity of representation forms, access to libraries and databases, possibility of creating discussion forums, of consulting experts, etc), the designers of educational software try to produce tools which imply other forms of work and other modes of regulation of learning activities. The variety of tasks with which the pupils are confronted leads to a diversification of the mental activities required from pupils. The designers generally have the concern of allowing learners to work in an autonomous way, according to their pace: to learn how to learn, to develop higher cognitive capabilities, to facilitate and optimise learning (Switzer, Callahan & Quinn, 1999), to encourage the creation of knowledge (Komis and Michaelides, 1996), such are the intentions which support the design of the ICTs. Their use is supposed, moreover, to allow the individualization of teaching. But what happens in reality? In fact, technology based learning environment exploits only part of the functionalities that the ICTs allow, for obvious reasons of the limits of pupils cognitive capabilities, especially young pupils. Indeed, in the process of learning, the cognitive treatments (seizure and coding of information, drawing inferences, reasoning, etc.) require the implementation of multiple controls which mobilize the working memory (Legros & Crinon, 2002). So, the learner is not very able to manage several tasks if the environment is too complex. It thus proves the necessity to conduct studies permitting to evaluate what the technology based learning environment really offers on the cognitive plane, considering the whole didactic system (pupils, professors and tools; Chaptal, 1999). Indeed, research on the effectiveness of the ICTs is far from agreeing in showing their superiority compared to traditional practices (Kulik, 1994, Chaptal, 1999, Wenglinsky, 1998).

The goal of the researches presented in this report is to analyse the uses the pupils can make with ModellingSpace and to evaluate the benefits for students's learning in several knowledge domains and educational levels.
As usually in the design of educational softwares, the development of ModellingSpace was done thanks to the exchanges between the conceptors and the researchers in education and in psychology working in collaboration with teachers, at various school levels.

During the conception of the software, studies were led in Belgium, France, Greece and Portugal. The researchers endeavoured to make echo of the encountered difficulties, which allowed an evolution of the software in the direction of a better adaptation to the users.

The studies have different aims and statutes. Firstly, they are simple tests to improve how the students use the software, in partnership with interested professors. At the same time the possibilities of the software and the situation-problems suggested to the students are evaluated. For this type of experimentation, the tools implemented in ModellingSpace proved to be very usefull because they allowed a fast diagnosis of the difficulties encountered by the students. In addition, pilots studies were led with the aim to test the validity of the projected methods of investigation (cf. D02). Lastly, systematic researches were led, with the aim to answer various questions relating to the use of the software.

Some of theses researches have been published (acts of congress, thesis and scientific articles)- cf. bibliography. Researches of this type are still under way.

The presentation of the systematic researches is privileged in this report.

On the basis of critical analysis of former work concerning the evaluation of the educational softwares (cf. D02) two types of systematic researches were led:

- researches having as objective to account for the cognitive activities of the students using ModellingSpace;
- researches having like objective to evaluate the pedagogical interest of using ModellingSpace in definite pedagogical contexts.

The report is thus structured in two parts corresponding to these two types of research.

For each research, we give detailed data so that future users of the software can have sufficiently precise information on the students' behavior. In the case of already published researches, only a summary of the results is presented.

Concerning the first type of research, the observers are always researchers in cognitive psychology or education, whatever the context where the pupils were invited to work with the software. Generally they use their personnal computer with a prototype version: first ModelCreator, then ModellingSpace.The role of the researcher is only to question the pupils or to observe them working together. He (or she) does not bring other information, only those planned in the experimental protocol. For the second type of research, they are voluntary teachers who took part in the studies. There it is a question of trying out the software under conditions having an ecological validity. In some cases, the teachers themselves were the subject of investigation. In this last case, very precise information on the material and human environment are given in order to be able to appreciate the observations. It is known indeed that the success of the innovations is conditioned by a multitude of factors as well human as material.

Although these two type of research were undertaken by separated teams, the continual exchange of information and investigation tools between the two teams allowed a synergy and a complementarity testified by the studies presented in this report.

3 OVERVIEW OF THE RESEARCH

3.1 Cognive evaluation of the software (France, University of Angers)

Educational level	Domain	Cognitive activities	Method	Data	Main result
Primary school (10 years old students) N = 16	Mathematic (proportionality)	Understanding Deduction Induction of relations	Interview and observation of dyads	Verbal transcriptions (video recorded) Models Video recordings	Facilitation Cognitive obstacles
Secondary schools N =	Physics (inclined plan)	Experimentation Prediction Deduction	Individual guided interviews Comparaison MS/*Physics by image*	Verbal transcriptions (audio recorded)	Relationnal traitment is facilitated when experimental activities preceed the use of MS MS is more adapted to students than Physics by image
University N =	Psychology (social interaction)	Construction of a conceptual map starting from the reading of a text	Observation of dyads in differents cooperative contexts	Verbal interactions (oral and written) Conceptual maps	Peer interactions are affected by cooperative context.

3.2 Case studies in real school environments (Greece, Aegean University)

3.2.1 Class of a Primary school (12 years old students), working with semiquantitative relations and object-oriented entities.

Learning Activities concerns problems with proportionality (Mathematics).

Main Scientific Concepts involved: time, volume of a liquid in a recipient, flow/flux. Experimental situation with real objects in conjunction with modeling through ModellingSpace, Duration: three sessions of 90 minutes. [3 x 45min].

The case study report presents results on the following:

(d) The possibility of young children to express themselves via ModellingSpace semantics concerning semiquantitative relations, their difficulties in some aspects, & specific points where ModellingSpace could create misconception to children when working during a few number of sessions,

(e) children' evolution on reasoning and expressing relations of proportionality,

(f) children' evolution in using related concepts.

3.2.2 Class of a Lower secondary school (14 years old students), working with semiquantitative relations and object-oriented entities.

Learning Activities concerns problems with proportionality (Mathematics).

Scientific Concepts involved: time, volume of a liquid in a recipient, flow/flux.

Experimental situation with real objects in conjunction with modeling through ModellingSpace. Duration: two sessions of 90 minutes. [2 x 45min].

The case study report presents research results on the following:

(d) the possibility of students 14 years old to express themselves via ModellingSpace semantics, & their difficulties in some aspects,

(e) students' evolution on reasoning and expressing relations of proportionality,

(f) students' evolution in using related concepts

3.2.3 Class of a Primary school (12 years old students), working (a) with semiquantitative relations and object-oriented entities, & (b) with concept maps.

Learning Activities concerns Chemistry problems related to Solutions.

Main involved concepts: => condensation & dilution of a solution, compounds, homogeneity of a solution).

Combination of real objects' Experimental situation with modeling through ModellingSpace (concept maps- models with semiquantitative relations – concept maps).

Duration: six teaching sessions of 45 minutes [6x 45min].

The Case study report presents research results on the following:

(d) The possibility of young children (12 years old) to be easily familiar with ModellingSpace semantics of concept maps creation and simple aspects of semiquantitative relations (implicating only two variables each time),

(e) the appropriateness of ModellingSpace environment and learning activities to support misconceptions appearance and then the evolution on scientific concepts construction,

(f) the ability of young students to work with concept maps and to progress via the whole set of learning activities related session.

3.2.4 Class of a Lower Secondary school (15 years old) working with (a) semiquantitative relations and object oriented entities & (b) quantitative relations.

Learning Activities concerns Physics problems related to Kinematics.

Main involved concepts => position, time, velocity, acceleration.

Familiar problems to be modeled via semiquantitative relations expressions and then quantitative ones.

3.2.4.1 Pilot study focusing on the role of object-oriented entities, their simulation and their effect in learning physics concepts.

The case study report presents research results on the effectiveness of a specific category of entities (the object-oriented entities with specific representation of motion variables), to make appear students misconceptions related to specific concepts (position, velocity as vectorial concepts) as well as their appropriateness to make students ideas evolve to the scientific ones.

3.2.4.2 Global results, from a 12 hours teaching unit, on modeling in physics, using semiquantitative and quantitative relations:

The case study report presents research results on the following:

(A) (a) understanding of representations: table of values and graphs , (b) modeling process, (c) teaching strategies

(B) The contribution of MS environment and worksheets on learning concerning: (a) the construction of a structured network of concepts, (b) the relations among specific concepts, (c) the distinction among independent and dependent variable, (d) the relation of proportionality, (e) the notion of a 'constant variable', (f) misconceptions and their evolution related to the concept of velocity, and the concept of position (g) students difficulties when they construct algebraic models.

3.2.5 Four Classes of a Lower & Higher Secondary school: Teaching & Learning during synchronous collaborative modelling through ModellingSpace among co-located students.

Unified case studies report taking into account, teaching sessions in four different class, and three different schools:

15 years old students (two classes & teachers in two different schools)

16 years old students in a technical high school

17 years old students in a technical high school

The Learning activities concerned mostly mathematics.

Students were involved in quantitative models, and in the use of these models in order to answer related questions.

Duration: eight teaching sessions: [8x 45 minutes]

The Case studies' reports present research results on the following:

8. The tools that support teachers for collaborative learning activities implementation and management during (online) and after (offline) the collaboration sessions.

9. The meaning, the quality, and the strategies of synchronous collaborative problem solving through MS for the specific modes of use.

10. The comparison of the modes of use.

11. The motivation of students to work on collaborative modelling activities

12. The students and teachers point of view for the learning value of collocated collaborative problem solving using MS.

13. The study of teachers' interventions and their consequences when they participate/supervise or guide the synchronous collaboration between two students.

14. Students' ideas about models and modelling after ModellingSpace based collaborative activities

4 COGNIVE EVALUATION OF THE SOFTWARE

4.1 Cognitive strategy to induce relational approach at ten years old (end of primary school) : the proportionality

(Sophie Ferret, Aurélie Lainé, Michel Perraudeau, Olivier Villeret, Annick Weil-Barais, University of Angers, France)

We chose to propose an activity relating to proportionality for several reasons: in the French school system, proportionality corresponds to an important moment in the teaching of mathematics in the primary education, continues during the college and appears necessary in many fields like physics and chemistry. The difficulties encountered by pupils also held our attention. Being a largely studied field, it is interesting to compare the procedure employed by the students using ModellingSpace compared to procedure eployed in other contexts (Vergnaud, 1994, Perraudeau, 2002).

We will first present the activities suggested to the pupils, then the context of the study, the characteristics of the population and finally the results.

4.1.1 Presentation of the activity

4.1.1.1 Questions or assumptions related to the activity content and conception

The pupil is brought to handle various entities like the budget of the holidays, the number of travellers, the cost by traveller, the cost of lodging and the duration of the voyage as well as the semi-quantitative relation and the quantitative relation. We are mainly interested to the way pupils interpret the modifications (which appear on the screen during simulations) and express the relations between the factors.

The questions are the following:

- Discovery of entities: how do pupils interpret the modifications of the entities according to available information (figurative and numerical modifications)? Which relations do they make between the numbers and the values of the entities?
- Discovery of relations: how do pupils interpret simulations according to available information (figurative and numerical modifications)? How do pupils interpret the semi-quantitative relations?

- how do pupils interpret the failure of the simulation?

- how do they interpret the graphs?

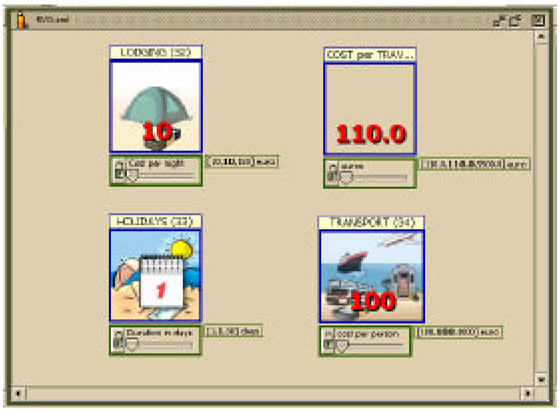
- which models are they able to build after a guided exploration phase?

4.1.1.2 Description

The activity is conceived in order to lead the pupils to discover elements of the software. These elements will enable him to build the model " budget of holidays= number of days*cost of lodging + transport ". Thus, the observer permits to the pupils to discover the various entities, presenting intermediate models (2 or 3 entities connected), semi-quantitative relation and quantitative relation.

- <u>discovery of entities</u>

The pupils observe the screen and interpret the entities:



- without numerical value;

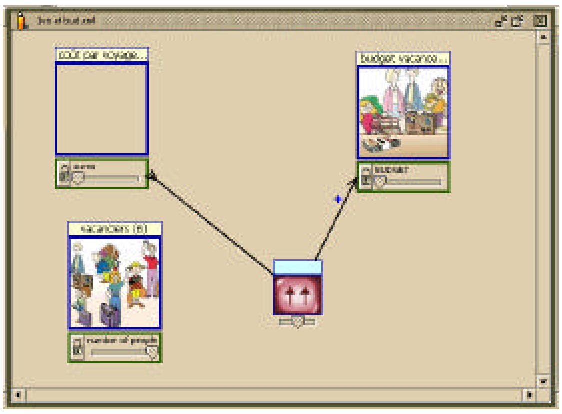
- with the scale of values (minimum, current value and maximum);

- with the current value (red number) in addition to the scale of values.

The observer encourage the pupil to notice the changes which appear on the screen (values for example) by raising questions as "what occurred?" and to find the significance of the values (to what do the numbers correspond?).

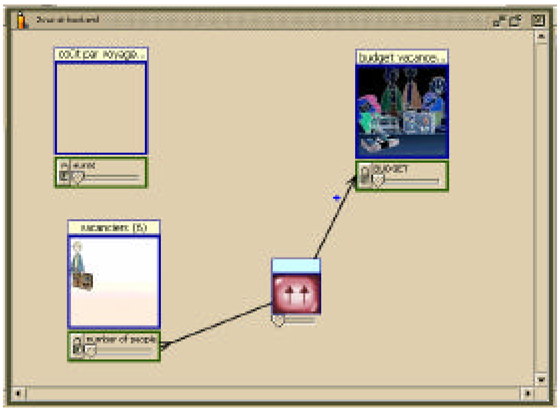
- <u>Discovery of relations</u>

- relation between budget of holidays and cost by traveller:



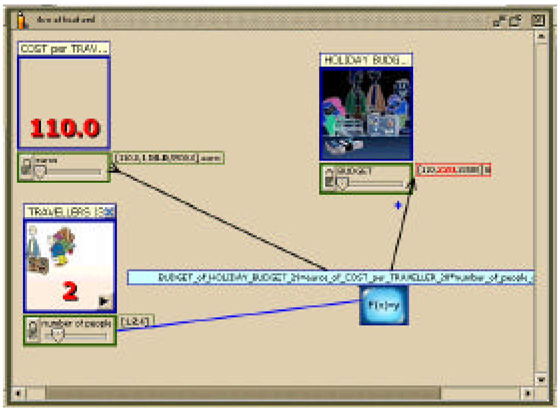
One is interested in the way the pupils interpret simulation and the relation between the two entities. Pupils are invited to describe what they see on the screen ("what happened?") and to interpret the semi-quantitative relation between the two entities (↑↑) ("why did we choose this relation?"). Sometimes, the requires to specify the choice of the relation compared to other relations (↑↓) ("could one put this relation and why?").

- <u>relation between holiday budget and number of traveller</u>:



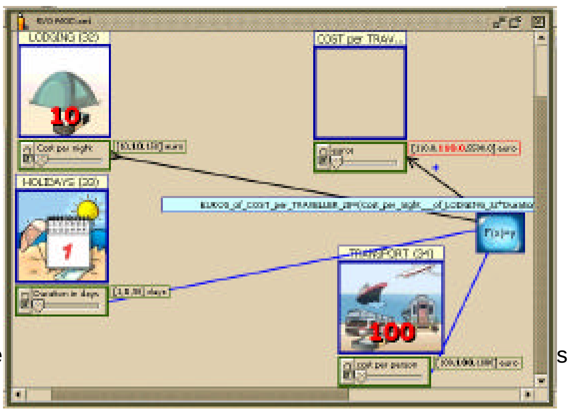
One studies the explanations given by the pupils concerning the failure of the simulation. The simulation failure corresponds to a relation between two factors which do not have the same unit. The observer asks questions about the image modifications (it becomes black) "what happened?" and this failure "why does it not work?”

- <u>relation holiday budget =cost by traveller*number of travellers</u>:



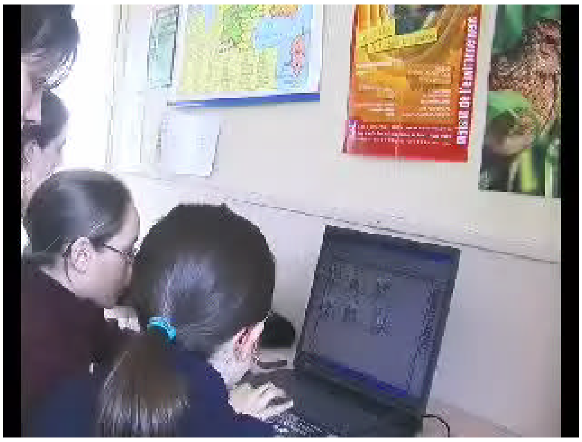
Pupils have to deduce the mathematical formula starting from model simulation ("what can we deduce?"). The observer can also present the numerical values to help pupils to find the constant. After having written the formula, the pupils changes the value of the constant and observe the modifications on the screen.

- <u>the graph</u>: pupils interpret what they see "what can we say?"
- <u>construction of the model holiday budget =lodging*number of days+ transport</u>:



The observer presents the various entities to the pupils; after, the observer proposes to choose the relations between the various factors: in order to facilitate the resolution of the problem, the observer proposes to the pupils to seek the mathematical formula starting from the numerical values (on a white sheet) before building the model on the screen.

4.1.2 Context of the study



- Version O.92b of ModellingSpace
- School : Angers, ◆Alfred Clément (Mr Perraudeau, *IUFM Pays de Loire*) ◆René Gasnier (Mme Jamil)
- Classroom : CM2 (end of primary school)
- Number of pupils : 16 pupils divided into 8 dyads
- Activity : the travel
- Duration of sequence : 60 minutes
- Place : classroom

- Role of researcher : the activity is directed by the observer with questions as "what happened?" (observation of the modifications) and "what can we say?" (request for explanation). The observer can also guide the pupils so that they can solve the problem.

Example of the observer's interventions (A: the observer; F&G: 2 pupils):

A : tu es sûre, regarde bien. Pourquoi le budget vacances, il est pas égal au coût par voyageur ? (are you sure, looks at well. Why does the budget of holidays is not equal to the cost by traveller?)

F : celui là, il est plus en avance que l'autre. (this one is more in advance than the other)

A : il est plus grand. (it is larger)

F : oui, le nombre est plus grand. (yes, the number is larger.)

A : et de combien ? Est-ce qu'ils augmentent pareil ? (and of how much? Do they increase similar?)

G : non, il y a 650 de plus. (not, there are 650 more.)

A : oui, il y a 650 de plus et là ? (yes, there are 650 more and there?)

G : 750 de plus. (750 more)

F : il y en a 100 de plus à chaque fois. (there are 100 more each time.)

A : au minimum c'est 110, si je mets celui là à 110, il se met à/ Pourquoi ? (at least there are 110, if I put that at 110, it /why ?)

F : il est 2 fois plus grand que l'autre, à chaque fois il est 2 fois plus grand. (it is 2 times larger than the other, each time it is 2 times larger.)

A : pourquoi le budget vacances serait 2 fois plus grand que le coût par voyageurs ? Parce qu'il y a .(why the budget of holidays would be 2 times larger than the cost by travellers? Because there is)

F&G : il y a 2 personnes. (there are 2 people.)

The observer also requests the expression of the ideas of all the pupils of the group.

- Context of situation : the observer makes work the pupils by group of 2. The pupils are installed at the bottom of the room (whereas the professor and the other pupils are in the classroom), in front of the screen of the computer and a camera films the pupils, the observer and the computer.

4.1.3 Population

- Questions or assumptions related to pupils :

The activity corresponds to a traditional problem in proportionality teaching : pupils of CM2 (end of primary school) should not encounter difficulty in the problem solving because the mathematical relations are simple multiplications (budget of holidays=cost by traveller*number of traveller).

- Number of pupils : 16
- Age of pupils : 10 years old
- Other characteristic : 7 boys et 9 girls.

4.1.4 Collect of data

- Material used to collect the information:

From the camera recordings, we retranscribed the interventions of the observer as well as the answers given by the pupils during the activity. The retranscriptions do not appear in this document.

- Type of data used for results analysis :

We carry out content analyses starting from the verbal answers of the pupils and for each type of spot: the analysis unit is the group, we will thus be interested only in the answers given by the group (the two pupils). These data appear in various tables presented in appendices.

4.1.5 Data analysis

Separate analyses were led for each task suggested to the pupils. For each task, the categories of answers and their distribution are specified. These distributions are given only as an indication to suggest the diversity of students'responses. Indeed, being given the weakness of the sample observed, it is not possible to make generalizations.

4.1.5.1 discovery of entities (without numerical value).

The data which appear in the table 1 (of the appendix) are answers of the various groups concerning the variation of the entities*: « il y a de plus en plus de personnes » (there are more and more people).*

In a general way, the groups express the variation of the entities (the three groups which did not expressed were not invited to do it). Pupils note the increase, the change of category or precise the values variation of the factors (gr. 7).

4.1.5.2 discovery of entities (with the scale of values)

The datas (cf. table 2 of the appendix) correspond to the answers given by the pupils to the question "to what correspond these numbers (on the scale of values)?". The answers categories are the following ones (they are not exclusive):

- value of entity. Pupils answer that the figures correspond to the values of entities : *"le nombre de personne"* *(the number of traveller)*.
- mistake. It is about interpretation mistake starting from the scale of values observation: *"1 virgule 3"* *(1 comma 3).*
- Increase. Pupils indicate a progression between the 3 scale values: *"ça augmente"* *(that increases).*
- Scale significance. Pupils indicate that the smallest value corresponds to the minimal value (on the scale), the medium value corresponds to the current value, and the largest value corresponds to the maximum value: *« enfin 1, 3 et 6. Là le minimum, là c'est ce que l'on a et là, c'est le maximum. »* *(finally 1, 3 and 6. There the minimum, there it is what one has and there, it is the maximum)*.

The repartition of responses is indicated in the table below.

Discovery of entities (scale of value)	**N (dyads)** 8
value	6
mistake	3
increase	6
Scale signifiance	6

Pupils establish the link between the numbers and the value of entity (a number of traveller, price). They mention the values increase on the scale and the majority of them says to what correspond these values (minimum and maximum). It is noted however that they encounter more difficulties to give the central value of the scale (current value).

4.1.5.3 discovery of entities (with current value)

The table (cf. table 2 of the appendix) presents the types of answers (non exclusive) to the question "to what corresponds the red number (current value)?". The answers categories are the following ones (they are not exclusive):

- value of entity. Pupils answer that the red number corresponds to the value of entity : *"au prix"* *(to the price)*.
- Number on scale. Pupils answer that the red number corresponds to the medium value : *"celui du milieu"* *(the medium)*.
- Current value. Pupils answer that the red number corresponds to the value taken by the entity : *« en fait je pense que c'est le nombre en rouge, c'est plutôt là où t'en es»* *(I think that it is the red number, it is rather where you are).*

The repartition of responses is indicated in the table below.

Discovery of entities (current value)	**N (dyads)** 8
value of entity	4
Number on scale	4
Current value	2

Pupils (6 groups) answer that the red number corresponds either to the medium value on the scale or to the current value (" where one is "). One can notice that only pupils who expressed themselves on the current value at the preceding phase, say that the red number corresponds to the value taken by the entity.

4.1.5.4 discovery of relations (budget of holidays/cost by traveller)

The table 4 (cf. appendix) presents the pupils answers types and interventions concerning the model simulation and the choice of the relation. The answers categories are the following ones (they are not exclusive):

- Changes. Pupils indicate the difference which appears on the screen between the budget variation (the cursor stops before the end and moves more slowly) and the cost by traveller variation (the cursor goes until the end and moves more quickly): *« quand ça va à fond/ quand le coût par voyageur ça va plus vite. » (when that goes thoroughly / when the cost by traveller that goes more quickly).*
- Topology. Pupils think that the two entities are dependent so that the cost by traveller money circulates towards the budget of holidays. The arrows (direction) connecting the two entities are interpreted as the money circulation between the first and the second entity: *« le budget vacances était en bas, puis il y avait une personne avec un petit tas d'argent, après dès que le budget vacances est monté, l'argent est descendu, donc il y en avait plus. » (the budget of holidays was in bottom, then there was a person with a small money heap, after as soon as the budget of holidays increased, the money decreased, therefore there was no more).*
- Sequence. The semi-quantitative relation (with the 2 arrows) is interpreted in a sequential way. One also finds this type of answer when pupils interpret the changes on the screen: *« là ça monte, là ça monte aussi » (there that goes up, there that also goes up).*
- Covariation. Pupils express the relation of covariation between the two entities: *« ça fait augmenter le budget vacances, parce que plus on paie, plus ça augmente le budget" (that made increase the budget of holidays, because the more one pays, the more that increases the budget).*

The repartition of responses is indicated in the table below.

Discovery of relations (cost trav/budget)	N (dyads) 8
Changes	2
Topology	3
Sequence	6
Covariation.	3

Pupils rather have a sequential approach of the relation between the two variables (6 groups): they describe each variable behavior ("that increases" and "that increases") but do not evoke the relation between these two variables. Pupils difficulty is to have a covariation approach of the entities: only 3 groups express the relation between the variables in term of "the more, the more" or "if, then". It is interesting to note that 3 other groups base their interpretation starting from the model structure on the screen (topology): the entities variations would be explained by the money circulation (budget/cost) between the first entity and the second entity. One can suppose that this interpretation comes from the observation of the entities variation difference.

4.1.5.5 discovery of relations (number of traveller/budget of holidays & budget of holidays=cost by traveller*number of traveller)

The table 5 (cf. appendix) presents other types of pupils interpretations concerning the relations between entities (second and third models). Even if pupils express themselves less on the relations than for the first model, other types of interpretation appear:

- Changes. Pupils indicate the modifications they observe on the screen concerning the difference of the various factors variation*: « le coût par voyageur, ça va plus vite que budget vacances. » (the cost by traveller, that goes more quickly than budget holidays).*
- variable/constant. Pupils have difficulties to differentiate constant and variables: *« je comprends pas parce que normalement les vacanciers, ça devrait bouger normalement, ça devrait bouger ensemble » (I do not understand because normally the travellers, that should move normally, that should move together).*
- other factor. Pupils interpret the variation difference between the two factors by the intervention of a third factor: *« parce que le budget, c'est aussi quand on est sur place" (because the budget, it is also when one is on the spot).*
- Constant. Pupils interpret the variation difference with the constant value. For that, they proceed by a problem resolution with numerical values: *« il est 2 fois plus grand que l'autre, à chaque fois il est 2 fois plus grand. » (it is 2 times larger than the other, each time it is 2 times larger).*
- sequence : (cf. table 5 of the appendix).
- covariation : (cf. table 5 of the appendix).

The repartition of the responses is indicated in the table below.

Discovery of relations **(traveller/budget of holidays & budget of holidays=cost by traveller*number of traveller)**	**N (dyads)** 8
Changes	4
variable/constant	2
other factor	1
Sequence	1
Covariation.	2

During the activity concerning the model “numbers of travellers/budget”, a group expresses the relation in term of covariation. However, the interest is to observe the various interpretations based on the factors variation differences. One could see previously that the advance of the cost by traveller on the budget could obstruct pupils: this difficulty concerns the group 2 which explains the difference by the intervention of another factor. But this difference can also be used to show the role of the constant: while proceeding by a resolution with values, pupils discover that the budget value is higher than the cost by traveller value because of the constant. Thus the model understanding is related to the differentiation between constants and variables and one can see that this differentiation presents a difficulty for some groups (gr. 1 and 6).

4.1.5.6 interpretation of simulation failure

The datas correspond to the pupils explanations types concerning the model simulation failure (the model connecting two entities which do not correspond to the same unit category) – cf table 6 of the appendix.

- Report. Pupils justify the failure by indicating that the two entities do not go together: *« ça va pas ensemble” (that does not go together).*
- another explanation. Pupils make interpretation mistakes compared to what they observe on the screen (or give another type of explanations): *« parce que il y aurait trop par rapport au nombre de vacanciers et au budget vacances, ce serait trop” (because there would be too much compared to the number of travellers and the budget of holidays, it would be too much).*
- Different unit : Pupils give explanations as *: « ce n’est pas la même unité » (it is not the same unit). «oui parce que je sais, c’est de l’argent alors que là, c’est des voyageurs, c’est des personnes, c’est pas la même unité quoi » (yes because I know, it is money whereas there, they are travellers, they are people, it is not the same unit).*

The repartition of responses is indicated in the table below.

Interpretation	**N (dyads)** 8
Changes	4
variable/constant	2
other factor	1
Sequence	1
Covariation.	2

The observer leads pupils to give failure explanation even if the groups propose other explanations or do not know how to explain it. Among the other explanations, one finds the pupils difficulty to interpret the difference between factors ("because there would be too much compared to the number of travellers and the budget of holidays, it would be too much").

4.1.5.7 interpretation of graphs

The data which appear (cf. table 7 of the appendix) are pupils interventions during the graph simulation answers to the questions raised by the observer ("To what does it correspond?"). The answers categories are the following ones (they are not exclusive):

- increase. Pupils indicate that it is about an increase, without specifying the relation between factors: *'à chaque fois, ça monte" (each time, that goes up).*
- prediction. Pupils predict the position of the following curves by specifying that the increase depends on the constant value: *"elle monte plus haut que la deuxième. Avant il y avait qu'une personne donc ça montait moins, je pense que si on met 3 et qu'on fait lecture, ça montera encore » (it goes up higher than the second. Before, there was a person, thus that went up less, I think that if 3 are put and that reading is made, that will still go up).*
- Value of entity : Pupils answer that the graph corresponds to the budget of holidays : *"budget".*
- another representation. Pupils establish the link with the preceding activities by specifying that the graph corresponds to another way of representing the model: *« c'est une autre manière de représenter. » (it is another manner of representing).*

The repartition of responses is indicated in the table below.

Discovery of graphs	**N (dyads)** 8
increase	4
prediction	5
Value of entity	4
another representation	2

With pupils predictions (5 groups), that one observes the link which they establish between the model and the graph: it seems that the difference between constant and variable is specified for some (gr. 3, 6, 7, 8) ("it goes up higher than the second. Before there was that a person thus that went up less, I think that if 3 are put and that reading is made, that will still go up").

4.1.5.8 model construction (budget of holidays=cost of lodging*number of days +transport).

Two types of approaches were considered: for groups 2 and 3, the observer starts by requiring to locate the variables and the constants ("the price, it will vary?", "the cost of lodging, it will depend on what?"). Pupils proceed then by a numerical resolution to find the mathematical formula:

> A : par le nombre de jour./donc le logement, on sait combien il coûte pour une nuit et combien de nuits on va rester, donc le coût total du logement ? (the number of days/ thus, the lodging, one knows how much it costs for one night and how many nights ones will stay, therefore, the total cost of lodging?)
>
> G1 : le coût total sachant combien de nuit on va rester/ (the total cost knowing how many nights one will stay)
>
> A : on le sait, c'est 7/ (we know, it's 7)
>
> G2 : 700 euros. (700 euros)
>
> A : et comment tu as trouvé ça 700 euros ? (and how did you find 700 euros ?)
>
> G2 : on fait 100 multiplié par 7. (one makes 100 multiplied by 7)
>
> A : on multiplie le prix d'une nuit. (one multiplies the one night price)
>
> G2 : multiplié par le nombre de nuit. (multiplied by the number of night)

The other groups start directly with the numerical resolution. One can notice that pupils do not encounter a particular difficulty to find the formula with the values.

4.1.6 Conclusion

The observations related to pupils at the end of the cycle of primary education put forward the fact that the pupils of this level are able to use the ModellingSpace software. The selected entities are correctly interpreted by the pupils. However, the interpretation of simulations reveal obstacles already described in other studies as, for example, the interpretation of the modifications in terms of sequential or topological relations.

The observations draw the attention to the need, for some pupils, to make sure that they suitably interpret information on the screen. Conversational analysis reveal that the ambiguity can be resolved during peer interaction supported by teacher (researcher in the study reported). What the pupils perceive on the screen is an object of conversation. The exchanges lead sometimes to the awakening and the clarification of the relational nature of the arithmetic operators. It is the more interesting fact to point out because the observer (a researcher in psychology) had only to question the pupils on the signification of the semiotic representation on the screen. It seems reasonable to think that the success of the pupils to the last task (to build a relation allowing to express the budget of holidays) is due to the progression suggested to the pupils: interpretation of the entities, interpretation of a covariation relation , interpretation of the simulation of a relation, interpretation of graphs, and then, research of a relation. It is undoubtedly the succession of evaluation tasks and production tasks which allowed to the pupils a research task of a new relation involving the use of multiplication. At this school level it seems that a preliminary work about the signification of relation and simulation is benefit.

4.1.7 Appendix

TABLE 1 : DISCOVERY OF ENTITIES (without value)

Gr	Variation
1	« il y a de plus en plus de personnes. » « il y en a plus/ une tente c'est pour 2 personnes et puis une maison c'est pour. » « oui/ ça dépend, il y a des maisons plus chères. »
3	« ça augmente le nombre de jours. » « ça a augmenté aussi. » « là aussi ça a augmenté, là ça a changé de bâtiment/» « il y a plus de monde. »
4	« au fur et à mesure. » « ça dépend où on va. » « là, il y a une grande maison qui doit coûter cher. » « ça augmente. »
6	« le nombre de personnes qu'on emmènera. Combien va coûter le voyage par rapport à ce que l'on prend. » « combien on va payer. » « une tente puis une maison. » « le prix que l'on doit payer par rapport à ce que l'on prend comme logement. »
7	« différent, plus ou moins d'argent, là c'est pareil pour le logement et le coût du voyage, et le budget, enfin le nombre de vacanciers, là ça augmente. En fait on fait varier l'argent , le transport, ça coûte plus ou moins cher. »

TABLE 2: DISCOVERY OF ENTITIES (scale of value)

Gr	Value of entity	Mistake	Increase	Scale signification
1	« en jours. » « du budget vacances. »		« 14 jours parce que si on revient au début, ça va faire 1, 1 et / il y a le 1, ça part du 1 et après/ 30/ et ensuite au milieu c'est en fonction de/ »	« c'est le début d'argent.»
2	« ils mettent combien il y a d'euros. »		« ça monte quand même. »	« oui, c'est le minimum. »
3	« de l'argent.»		« on va le prendre, ça va augmenter. »	
4	« au nombre de personne. »	« je comprends pas, parce qu'au début on a 1 et après un 6. »	« ça augmente. »	
5		« là je pense que c'est le maximum de budget. » « 1963 parce qu'il est en gras. »	« j'ai compris, c'est qu'au début on a 1960 euros et plus on va loin, plus ça augmente. »	« en fait c'est le minimum et le maximum. » « c'est là où on en est. »
6	« le nombre de personnes. »			« donc là, il y a 6 personnes qu'on peut prendre, le maximum c'est 6 et le minimum c'est 1. »
7		« 1 virgule 3. »		« enfin 1, 3 et 6. Là le minimum, là c'est ce que l'on a et là, c'est le maximum. »
8	« Oui, c'est le nombre de personnes. »		« au début, il y en a 1 et puis il y en a 6. »	« c'est normal que le plus petit c'est 1 et le plus grand c'est 6. »

TABLE 3 : DISCOVERY OF ENTITIES (current value)

Gr	Value of entity	Number on scale	Current value
1	« que c'est 10 euros pour la tente, 100 euros pour le transport. »		
2	« aux euros. »	« à celui en gras. »	
3		« c'est le nombre (du milieu). »	
4	« au prix. »	« au nombre qui a marqué en gras. »	
5			« là par exemple, il y a une personne et il y a un chiffre, le nombre 1. » « en fait je pense que c'est le nombre en rouge, c'est plutôt là où t'en es » « c'est peut-être un peu pour mieux voir parce que si on a pas trop remarqué que c'est ici que ça change. »
6			« par exemple, en ce moment il y a 3 personnes, donc il y a marqué le chiffre 3. »
7			
8	« c'est au nombre de personne. »	« celui du milieu. »	

TABLE 4 : DISCOVERY OF RELATIONS (COST TRAV/BUDGET)

Gr	Changes	Topology	séquence	covariation
1		« on part du coût par voyageur / ensuite ça repasse par le budget vacances ? » « le budget vacances était en bas, puis il y avait une personne avec un petit tas d'argent, après dès que le budget vacances est monté, l'argent est descendu, donc il y en avait plus. »	« peut-être que celui là il descend et celui là il monte. » « il va augmenter aussi. »	
2				« ça fait augmenter le budget vacances, parce que plus on paie, plus ça augmente le budget. » :« ça veut dire que si ici ça augmente, ici ça augmente. » « ça veut dire que plus le coût du voyageur coûte moins cher, plus le budget coûte moins cher aussi. »
3			« quand ça augmente là, ça augmente ici. » « et ça a aussi augmenté là. » « parce que ça augmente les 2/ ça veut dire qu'ils montent en fait. »	
4			« parce que ça grandit. » « là, ça a augmenté. » « là, ça a augmenté aussi. » « là, il y a des petits plus donc peut-être que ça veut dire que le coût du voyageur et le budget vacances ça fait la même chose, ça augmente en fonction des nombres. »	
5				« parce que je pense que ça fait, l'icône comme vous avez mis, ça fait, si on monte le coût par voyageur, ça fait monter le budget vacances. »
6	« là, ça fait le maximum (coût voy), là ça fait un quart (budget). »	« là, il y a l'argent qui apparaît (L). L'argent, il baisse. » « il y a juste un billet. » « en fait, les billets qui sont là (coût voy), il les met là (budget). »	« parce que il y en a un qui monte et l'autre qui descend. » « parce que les 2 montent. »	
7			« il y en a une qui baisse et il y en a une qui »	« et oui, mais l'autre tu peux pas, ça baisse, si tu baisses le prix du voyage, le budget vacances, il va baisser pareil. Puisque si on monte »
8	« quand ça va à fond/ quand le coût par voyageur ça va	« parce que il y a une flèche en haut, une flèche en bas alors. » « il y a quelque chose en dessous et	« parce qu'ils augmentent. »	

	plus vite. » « ils s'arrêtent en même temps et il y en a un qui avance plus vite que l'autre. »	il y a quelque chose au dessus. »		

TABLE 5 : DISCOVERY OF RELATIONS

Gr	Changes	Variable/constant	Other factor	Constant	sequence	covariation
1		« je comprends pas parce que normalement les vacanciers, ça devrait bouger normalement, ça devrait bouger ensemble. »				« plus tu as de vacanciers, plus le budget vacances va augmenter »
2	« le coût par voyageur, ça va plus vite que budget vacances. »		« parce que le budget c'est aussi quand on est sur place. »	« il est 2 fois plus grand que l'autre, à chaque fois il est 2 fois plus grand. »		« au nombre de jours qu'on passe, plus on passe de jours, plus c'est cher. »
3				« 170, à chaque fois on augmente le coût par voyageur. » « ça augmente de 40. »		
4	« c'est le maximum. »					
5	« il y en a un qui augmente plus vite que l'autre. »					
6		« oui, mais si on reste 10 jours, je comprends pas trop, parce que si on a 10 jours de toute façon, ça change pas ça. »			« le budget vacances va augmenter en même temps que le nombre de voyageurs va augmenter. »	
7						
8	« le curseur, il est à fond pour les vacances et le budget, il est au début. »					

TABLE 6 : INTERPRETATION OF SIMULATION FAILURE

Gr	report	Another explanation	Different unit
1	« ça va pas ensemble. »	« coût par voyageur et budget vacances, c'est proportionnel, que les vacanciers et budget vacances, c'est pas proportionnel. »	
2	« que ça marche pas, ça va pas ensemble. »	« le budget vacances et les vacanciers et puis en plus, si ils sont plusieurs, ils peuvent se partager le »	« parce qu'on calcule des euros avec des vacanciers. » « la même unité. »
3		« si, je crois que le nombre de vacanciers et le budget de vacanciers, il doit y en avoir moins, avoir moins de ça. »	« c'est pas la même catégorie. » « c'est pas pareil. »
4	« le budget et les vacanciers, ça a pas trop de rapport parce que »		« les 2 ensembles, ça a un rapport avec l'euro. » « là, on a des personnes. »
5			« parce que les vacanciers et les voyageurs, c'est à peu près. » « parce que c'est les 2 d'argent, tandis que eux il y a pas de billet. »
6		« parce que il y aurait trop par rapport au nombre de vacanciers et au budget vacances, ce serait trop. »	« je sais pas, mais si on reliait coût par voyageur et vacanciers, peut-être que ça marcherait. » « oui parce que coût par voyageurs et que les voyageurs, c'est des vacanciers, donc si on réunit les 2. » « oui parce que je sais, c'est de l'argent alors que là, c'est des voyageurs, c'est des personnes, c'est pas la même unité quoi. »
7			« non, on relie des personnes avec des personnes. »
8			« les vacanciers, c'est pas des euros. » « c'est pas la même chose. »

TABLE 7 : INTERPRETATION OF GRAPHS

Gr	Increase	prediction	Value of entity	Another representation
1		« plus tu en as, plus ça devient. »		
2	« le prix monte. »			« en fait c'est une autre représentation. »
3	" il monte, il monte. »	« est-ce que ça peut monter jusque là ? » « si on met 2 personnes oui. »	« budget. »	
4			« non le budget. »	
5	« à chaque fois ça monte. »		« l'argent qui est dans le budget. »	
6	« là, ça augmente et là ça. » « la courbe, elle monte. »	« si on met 6, il y aura 2 courbes de plus que »	« le prix qu'on va devoir payer. » « le budget. »	« c'est une autre manière de représenter. »
7		"elle monte plus haut que la deuxième. Avant il y avait qu'une personne donc ça montait moins, je pense que si on met 3 et qu'on fait lecture, ça montera encore. » « plus on va monter le nombre de personnes et plus ça va monter. L. Plus on va monter le nombre de personnes et il y aura plus de courbes. » « mais non ça va monter plus haut. » « la sixième, ce sera la plus haute. »		
8		"pour 4 voyageurs, ça va être le double de 2. »		

4.2 Carrying out physics experiments with ModellingSpace in secondary school (13-15 years old children)

(Zacharoula Smyrnaiou, Annick Weil-Barais, Université d'Angers, France).

The cognitive interest of ModellingSpace is to allow pupils to handle various semiotic systems, and to express entities and relations. It is possible to understand the compatibility or the incompatibility of the relational expressions by comparing the transformations of the entities which are represented in a figurative way by dynamic images and which are associated with various expressions of the relations. Students may explore the mapping between various ways of representing the relations: graphic coding with arrows of variable size (↑↑ which means the covariation of two descriptors), logical, mathematical expression, graph, and table of measurements, ModellingSpace (Komis et al., 1998; Politis et al., 2001). Thus the students can connect various symbolic notations of relations between variables and at the same time, we suggest processes of translation between the various semiotic systems (language, semi-quantitative relations, etc). This functionality appears to be very important in the case of scientific learning, which requires the apprehension of formal relationships, which are very difficult for pupils (Cuoco, 1994; Kaput, 1987; Goldin, 1987; Janvier, 1987; Lesh et al., 1987; Moschkovich et al., 1993; Monk, 1992). Indeed, it seems now established that the construction of a new symbolic system for pupils proceeds cognitively out of comparison of familiar representations and new representations (Duval, 1988; Weil-Barais & Lemeignan, 1989; Weil-Barais & Lemeignan, 1990; Weil-Barais 1990; Lemeignan and Weil-Barais, 1993). We should remember that the control of the meanings that the various semiotic systems, invented by different cultures to express relations between entities, constitutes a fundamental issue of scientific education. Without the knowledge of these semiotic systems, there is no possible science. The process of translation of the relations between the variables describing the entities which the software allows thus appears essential from the point of view of the learning of science.

4.2.1 Description of the study

4.2.1.1 Hypothesis

We start from the hypothesis that the process of translation between representation systems allow students to 1) learn the meanings of symbols, which at the beginning may be opaque to them; 2) familiarise themselves with symbolic systems; 3) understand them; and 4) help them choose the most pertinent formal systems.

4.2.1.2 Objectives

If the *a priori* analysis of the software is right, we can expect that the pupils who use it will have a different approach to the physical systems with which they are confronted. Used to formalize the constitutive entities of the systems in terms of properties and relations between dimensions, they should account for the transformations of the physical systems in a different way than the pupils who have only practical experiences of the physical systems.

The study was conducted in connection with a traditional situation studied in mechanics: the displacement of a vehicle on an inclined plan.

4.2.1.3 Problem

The problem suggested to the pupils is the following: " a car without engine runs on a road which can have a more or less acute slope". A series of questions are posed to the pupils aiming at leading them to be interested in the relations between speed and mass, speed and angle of the road, speed and type of the road, speed and time of displacement.
Example of the questions:

- Could you make it so that the car placed on the paper surface is made to move without you having to touch it?
- Which are the factors that have an effect on the speed of the car?
- On which surface (concrete, frozen, etc.) does the car move faster? Explain your answer.
- A car rolls on an inclined road slope. Imagine that a second car, larger this time, moves on the same road. Which car will go down faster? Explain your answer.
- Can you describe the state relationship between the speed of the vehicle and the duration of displacement?

The pupils have either a set of objects (cars and supports), or the `technology based learning environment`.

4.2.1.4 Description of ModellingSpace images

The screen of the computer shows the image of a car represented as an entity. We can describe it by its mass and speed (called ‘properties’ in ModellingSpace). The mass and the speed of the car can be modified. The modification of the mass is represented by three different sizes of cars. The modification of the speed is represented by an increase of the shade beyond the car as we see on the images reproduced in figure 1.

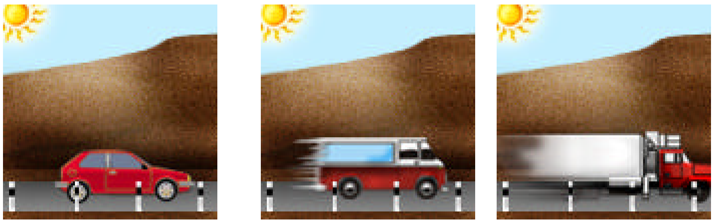


Figure 1 : the representation of the modification of mass and speed

The other image (entity) represents a road which has two properties: angle and type of road (that corresponds for us to the coefficient of friction, but we did not use this denomination because it is unknown to the secondary students to whom this task is addressed). The angle can have various values: the road can be horizontal or more or less tilted. The road surface can be icy, or wet, or made out of concrete or be a dirty road. (These images correspond to our representation of the coefficient of friction which is minimal (zero) in the case of icy road, maximum for the dirty road, the two other roads (wet and concrete) correspond to intermediate values, in the following order of the friction coefficient (figure 2).

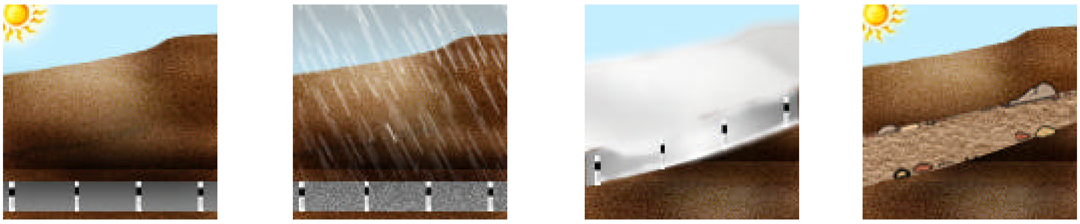


Figure 2 : Representations for the modification of coefficient of friction and the angle

On the screen, the image of a clock also appears, representing the time necessary for the displacement of the car. Time has the status of the independent variable compared to the other properties, which are the dependent variables.

4.2.1.5 Method

We compared the descriptions and manipulations made by the pupils when they had material objects (various plastic cars and various plane surfaces: paper, plastic …) to carry out the experiments and when they uses the ModellingSpace which makes possible to model and simulate symbolically the experiments. In so far as we can make the assumption that working on the objects and symbolic notations can have reciprocal effects, we counterbalanced the order of the conditions: a group of pupils worked initially with the technology based learning environment, then with the objects, the other group made the reverse (objects, then learning environment).
We conducted interviews with 26 pupils of college attending the classes of 8th (13-14 years old) and 9th (14 - 15 years old) located in the Paris area. The duration of each interview was 15 - 20 minutes. The pupils had volunteered to participate.

4.2.2 Results

The whole of given collected was the subject of a thesis in sciences of education (Smyrnaiou, 2003, under the direction of Annick Weil-Barais). So, we mention only the results concerning the pupils' understanding of the relation between the angle of the surface and the speed of the car. They are representative of the other results.

4.2.2.1 When the experiments are carried out with the computer

After the experimenter has successively set up, using the tools described previously (entities and properties), the various relations (between mass and speed, type of the road and speed, speed and angle), pupils are invited to look on the screen at the dynamic images which correspond to the formalization. The following question was put: "according to what you saw, can you say which is the relation between the speed of the vehicle and the angle of the inclined road? ". The second time they had to choose from a of iconic representations of relations, the one which was most appropriate and also justify their answer.

4.2.2.1.1 Relation between the speed of the vehicle and the angle of the inclined road

The answers are distributed in the following way:

- 20 pupils said that the car goes faster giving various explanations,
- 4 said that the car goes slower,
- 2 gave no conclusion on the speed but about the state of the road or evoke the acceleration.

These answers reveal that spontaneously the pupils focus themselves only on one property (mainly speed), sometimes making a mistake in the interpretation of the direction of the change in speed (4 out of 26 pupils). They do not express the covariation between the increase of the slope and that of speed.

4.2.2.1.2 Symbolic expression of the relation

When we ask them to choose the most appropriate symbolic expression, the majority of pupils (17/26) choose the relation which expresses the covariation (??). However other answers appear, often multiple (cf table 1).

Table 1: The relation between the speed of the vehicle and the slope of the plan

	1st relation (??)	2nd relation (??)	2nd 3rd relations (??) (?-)	1st 2nd 3rd relations (??)(??) (?-)	4th relation (¿?)	No relation	Total
8th (13-14 years)	8	3	1	0	0	0	12
9rd (14 – 15 years)	9	2	0	1	1	1	14
Total	17	5	1	1	1	1	26

4.2.2.1.3 Justifications

The verbal justifications of the pupils are of different nature. They are discussed below and their distribution is presented in table 2.

- Expressions of a co variation (COVA) or a contra-variation (CONTRA)

For example, a 13-year old pupil said: « …*the slope increases and the car goes more quickly* » (COVA). The pupils who chose the relation of covariation use suitable linguistic forms. The pupils who did not produce these relational expressions chose , instead semi-quantitatives relations erroneous or multiple, thus demonstrating their uncertainty.
Mistaken answers were also given due to the fact that the dynamic images were not perceived in the way the originators of these images expected it. For example, a 14-year old pupil mentioned: « *The more the slope increases, the more the speed of the car decreases* ». Another pupil explained that « *the more the car goes down, the more the road goes up* ». Another 14-year old considered that « *The more the inclination of the road …the more the car goes quickly* » (CONTRA). Thus, these pupils were led to choose the 2nd relation.
Such observations stress the importance of the understanding of the relations in natural language. The assumption that one can advance is that if the pupil is not able to understand the transformations relationally, in natural language, s/he is unable to do it with formal systems.

- Evocation of properties (POBJ)

This is the case when the pupil evokes only one of the properties of the object, for example a 13-year old pupil said: «*… it is faster* » and he chose the 1st relation.

- Conceptualisation (CNST)

Some pupils conceptualised the situation in physical terms of sizes. For example, a 13-year old pupil explained: «*The car accelerates when it is on a slope…*» and he chose the 1st relation.

- Sequential description (DESC)

Certain pupils described the movement when the car goes up and when it goes down, as if the two elements of the image and of the icon represented successive states of the movement. For example a 14-year old pupil affirmed: «when *the car goes down, it goes more quickly and when it goes up, it goes less quickly* ». Another indicated that « *the road goes up* (?) *and the car slows down* (?), *remains at the same point* » and there he chose the second relation (??). We found the strategy of sequential reading of the images and icons already described by other authors was an obstacle for understanding the variational approach of the relations (Baillé & Maury, 1993; Janvier, 1998).

The comparison of the given justifications according to whether the software was used before or after the experimentation with the objects (cf Tableau 2) underlines that the use of the variational expressions is more important when the pupils have experimented with the objects. The sequential treatment of the images and the icons is not very frequent (4 pupils out of 26) but it concerns particuliarly the pupils who used the software without doing any practical activities previously.

This result shows that only half of the pupils could adequately process the data presented on the screen of the computer and that they were more numerous if they had previously handled the objects represented on the screen of the computer.

Table 2: Justifications of the choice of the relational semi-quantitative expressions between the slope and speed

Categories	*ModelsCreator (used first)*		*ModelsCreator (used second)*		
	8th (13-14 years)	**9rd (14 – 15 years)**	**8th (13-14 years)**	**9rd (14 – 15 years)**	**Nb pupils**
Co-variation (COVA)	1	2	4	6	13
Contra-variation (CONTRA)	1	1	0	1	3
Properties of the objects (POBJ)	0	3	2	0	5
Conceptualisation of the situation (CNST)	1	1	1	0	3
Sequential description (DESC)	3	0	0	1	4
Other answers	1	1	0	1	3
Number of pupils	6	7	6	7	26[1]

4.2.2.2 When 'real' experiments are carried out

When the pupils carried out the experiment, the following question was put to them: When the slope of the plan increases, what happens with speed? (It does not change, it increases, it decreases). Explain your answer.

4.2.2.2.1 Predictions concerning speed

All the pupils, except one, answered that when the slope of the plan increases, speed increases too. Only one pupil said that it does not change: « *Bah! That does not change* ».

4.2.2.2.2 Explanation of the relation between the slope and speed

The arguments advanced by the pupils were of different natures. They are discussed hereafter and their distribution is presented in table 3.

- Relation of covariation (COVA) between the slope and speed (more…more). For example, a 14-year old pupil affirmed: « *The more the slope increases, the more the speed, while going down, will also increase* » or of contra-variation

[1] The total of this column is higher than the total number of pupils because a pupil can give several justifications.

(CONTRA): «*The more the slope is steep, the more… e, less the car is held back* ».

- Evocation of an object property (the car or the surface) accompanied with a comparative term of the « steeper, larger, stronger » (POBJ). For example, a 13 year old pupil answered: « *It (speed) increases because it is steeper there...* ».
- Putting a correspondence between the physical situation and its representation on the screen (CORR). For example, a 14-year old pupil who had already carried out the experiment with the software answered*:* « *it … returns to the same question* ».
- Mobilization of a physical concept like acceleration, push (CNST). For examples: «*Bah, the car, it will go always downwards* », « The car goes more quickly because *it has more time to accelerate. There is more space to accelerate*».
- Notation of the type: it will go more quickly, the wheels turn more quickly etc. (NOTI). For example, « *It increases because the wheels… e… that involve … the wheels turn more quickly* » (a 14-year old pupil).
- Expression of a feeling that it is normal or logical as « *it is normal, logical or it is obvious* » (OBVI). For example, a 13-year old pupil said: « *I do not know, it is obvious, that appears so obvious* ».

Half of the pupils (13 out of 26) justified by observation their prediction relating to speed according to the slope of the plane on which the car moves. This concerned in particular the pupils who had experimented with the objects. Those, who first used ModellingSpace did not seem to understand the experiments in a singular way. They do not put in correspondence spontaneously equate the experiment with what they before saw the screen.

Table 3 : Explanations of the relation between the slope and speed, if the pupils carry out the experiments with the material

Categories	***Experimentation with the objects after use of ModelsCreator***		***Experimentation with the objects before use of ModelsCreator***		
	8th (13-14 years)e	**9rd (14 – 15 years)**	**8th (13-14 years)**	**9rd (14 – 15 years)**	**Nb Pupils**
Covariation (COVA)	0	2	0	2	4
Contra-variation (CONTRA)	0	0	1	0	1
Properties of the objects (POBJ)	1	1	0	2	4
Put in correspondence (CORR)	2	0	0	0	2
Physical concept (CNST)	0	1	0	0	1
Notation (NOTI)	1	2	5	5	13
Obvious (OBVI)	1	0	1	0	2
Other answers	0	1	1	0	2

No explanation (NEXPL)	3	2	1	1	7
Number of pupils	6	7	6	7	26

4.2.3 Conclusion and prospect

If we compare the advanced explanations of the pupils according to whether they experimented with the objects and with ModellingSpace, it appears that the variational relational approach is much more frequent with the learning environment than with the objects (13 out of 26 in the first case, against 4 out of 26 in the second case). However, this approach appears especially marked when the pupils had experimented with the objects before the use of the technology based learning environment. These results, obtained with a small number of pupils, would need to be consolidated. Indeed, they draw attention to the cognitive benefit of the use of the learning environment if it is preceded by an experimental activity with the relevant objects.
The results obtained support the hypothesis that ModellingSpace constitutes a good tool to help pupils to understand the transformations of the situations into relational terms. However, they draw attention to the need for practical activities using the objects and the questions about them.
The limitation of the work presented is due to the conditions of data collection: individual interviews where we avoided bringing in other information than that provided by the activities themselves, with the objects or the software. Future studies with small groups of pupils will make it possible to specify the effects of the interactions between pupils.

4.3 Comparative approach : ModellingSpace versus 'physics by the image' at lower secondary school and upper secondary school

(Zacharoula Smyrnaiou, Annick Weil-Barais, University of Angers, France)

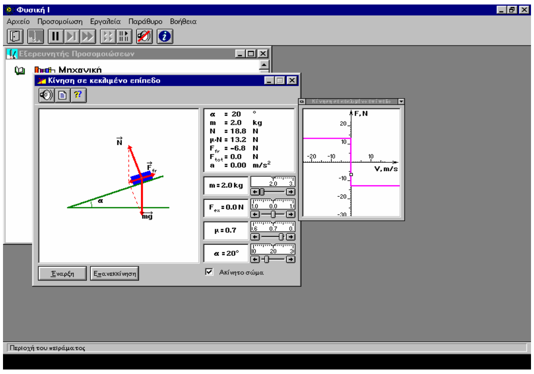
Advertissment

This study is reported in detail in the thesis of Zacharoula Smyrnaiou (Smyrnaiou, 2003, under the direction of Annick Weil-Barais). So we present here only a synthesis of the main aspects.

The comparison of technology based learning environment concerning different school levels can help users to proceed to rational choices, according to the aims in view. Interested by conceptualization processes and modelling learning, we selected two technology based learning environments conceived to help pupils of secondary education to initiate themselves with such a step: 'physics by the image' and ‘ModellingSpace’. In order to be able to compare pupils conduits compared to the possibilities offered by theses learning environments, we choose an identical field of study: the displacement of a vehicle on an inclined plan. Vergnaud’s work on the development of knowledge in children (Vergnaud, 1987) as well as other works carried out on the learning of modelling in sciences which stress the importance of the comparison between work on symbolic notations and empirical activities (Beaufils, 2000; Buty, 2000; Lemeignan & Weil-Barais, 1993; Malafosse, Lerouge & Dusseau, 2000; Martinand, 1992; Séjourné & Tiberghien, 2001; Vince, 2000).

4.3.1 The compared software"

'*Physics by image*' (Sciencesoft, 1998) is a technology based learning environment of simulation currently marketed in various countries. It makes it possible to approach the theoretical part of physics (recalls of course in the form of textual files and sounds, exercises) and into practice to put it with an experimental approach (interactive simulations, video). It is an interactive tool, which allows learning how to modify all the parameters of an experiment and to immediately visualize on the screen the effect of theses modifications on the phenomena.



"Figure 3. The interface of 'physics by image"

4.3.2 Questions of research and method

On the one hand, we want to know how pupils interpret the symbolic notations that appear on the screen; on the other hand, we wonder about what this technology based learning environment for the comprehension of the physical phenomenon brings.

For the two types of technology based learning environments, we ask on the one hand the pupils to carry out experiments with objects and on the other hand, to work on theses experiments using theses environments. Of course, questions are adapted to the specifications of these technology based learning environments. Half of the pupils observed work initially with objects (on objects form and variable mass, with more or less smooth supports), and then with the technology based learning environments. For the other half of pupils, the order is reversed. Pupils are seen in individual interviews recorded with a tape recorder. The analyses relate to the transcriptions of the entries of charge.

Two researches were carried out near pupils of lower and upper secondary school in public schools, in France, with each type of technology based learning environment.

4.3.2.1 With Physics by image

We ask the pupils to carry out experiments (to make so that the object is put moving on a surface, without touching it, making so that the object moves more quickly, less quickly, etc). When pupils have the computer, we asked them questions beforehand on the direction of the symbols and the icons that appear on the screen. With the exit of handling with the technology based learning environment and the objects, we ask them to describe the experiments in order to determine the conceptualisation that they make some.

For each experiment carried out, four categories of answers were distinguished:

· pupil cannot carry out the request neither with the objects, nor with the computer (C1);

· pupil can carry out the request only with the objects (lake of correspondence between the actions on the objects and the symbolic notations) (C2);

· pupil can carry out the request only with the computer (lake of correspondence between the actions on the objects and the symbolic notations) (C3);

· pupil is able to carry out the request with the objects and the computer (correspondence between the actions on the objects and the symbolic notations) (C4).

Although it is about a very simple experiment, much of pupils of lower secondary school do not manage to carry it out. Even if pupils are able to carry out the experiments manually, they are not necessarily able to do it using the technology based learning environment.

We raise an important evolution of descriptions between lower secondary school and upper secondary school mainly ascribable to the school learning. The representation implies conceptualisations, which do not concern only individual cognitive activities since the mobilized concepts concern instituted fields of knowledge. The answers of pupils of upper secondary school (year 10: i.e. 15 year-old pupils) are close to those of the pupils of lower secondary school (year 8 and year 9: i.e. 13-15 year-old pupils): their description of the experiments are centred on handling which they made and on the perceived events. The pupils of upper secondary school (year 11 and year 12: i.e. 16 and 17 year-old pupils) in science section express the experiments in physical terms of sizes. The evolution observed confirms former observations (Lemeignan & Weil-Barais, 1988,1993; Weil-Barais & Lemeignan, 1990).

Pupils of lower secondary school (year 8 and year 9) and pupils of upper secondary school (year 10) do not have access to the significance of the physical sizes represented symbolically (in particular force and coefficient of friction) and they are not able to vary them. As long as icons and signs appearing on the screen do not have the statute of representational systems of physical situations (in other words, of the models), they cannot be employed by pupil to simulate experiments. Only pupils in science section (year 11 and year 12) who have an access to the significance of symbols give richer answers when they work with the technology based learning environment that when they test with the objects.

When we compare descriptions, which pupils made of the experiments carried out with the objects, according to whether they used the technology based learning environment or not beforehand, we realize that those differ little, except for pupils in science section (year 11 and year 12). The latter provide richer descriptions when beforehand they used the technology based learning environment. It seems thus that when pupils control beforehand the system of formalization established in the technology based learning environment, using the environment encourages them to use this system, which they do less when they are confronted first with the material. All things considered, for these pupils already advanced in the learning of physics, the use of the technology based learning environment enables them to mobilize their knowledge to apprehend experimental situations. For the other pupils, the formal system that they are invited to use does not make it possible for them to modify their description of the phenomena.

4.3.2.2 With ModellingSpace

The problem suggested to the pupils is as follows: " a car without engine runs on a road which can have a more or less acute slope". A series of questions are posed to the pupils aiming at leading them to be interested in the relations between speed and mass, speed and angle of the road, speed and type of the road, speed and time of displacement.

As opposed to what we observed with the other technology based learning environment, the fact of using beforehand the technology based learning environment before carrying out the experiments produces beneficial effects on the quality of descriptions made of the experiments: the majority of pupils use the properties of the entities which they saw in the technology based learning environment to answer to the questions. The visualization of the entities (variable), the properties and the relations [4], [12], realized with the ModelCreator helps pupils thus to conceptualize in an analytical way the situations, and this as of the lower secondary school. Almost all the pupils of the lower secondary school succeed in carrying out the experiment, undoubtedly thanks to the visualization of entities in a pictorial form (vehicles of variable size, roads more or less smooth …) and properties (indicated by words and not in a formal way).

Pupils who carry out initially the experiment with objects and which did not interact yet with the ModelsCreator make a phenomenological description of the objects, perceived handling and events and use several descriptors which are not relevant.

In addition, it appears that the variation relational approach is much more frequent with the technology based learning environment than with the objects (for example, if the angle increases, speed increases). However, this approach appears especially when before the use of the technology based learning environment, the pupils tested with the objects. These results stress the importance of the apprehension of the relations in natural language. The assumption that one can adva nce is that if the pupil is not able to apprehend transformations relationally, in the plan of the natural language, he is unable to do it with formal systems.

4.3.3 Comparison of the results

Although it is about a very simple experiment, much of pupils of lower secondary school do not manage to carry it out. Even if pupils are able to carry out the experiments manually, they are not necessarily able to do it with ‘Physics by image’ because they do not have an access to the significance of the symbols. On the other hand, with ‘ModellingSpace, even the pupils of lower secondary school are able to carry out the experiment thanks to the visualization of the entities, with the expression of the properties in natural language rather than by letter symbols and with the formalization of the relations by means of graphic codes (of the directed arrows various lengths to translate the importance of the variation).

4.3.4 Conclusion and prospects

The comparison between the pupils’behavior in the two types of technology based learning environments underlines the need of a comparison between the aspects of reality, their conceptualisation and the symbolic notations of those. The learning of physics rests in fact on this type of comparison. The use of the technology based learning environments can facilitate these comparisons, provided that it intervenes jointly with the concrete realization of experiments especially for pupils of lower secondary school who do not control yet the tools for formalization. It proves that the representation of entities, properties and relations in a figurative form meaning for the pupils (case of ModellingSpace) enables them to use the technology based learning environment in a way meaning compared to the world of actions, objects and events. This type of technology based learning environment thus seems to help pupils with the conceptualisation of the situations. This enables them to be detached from the actions and the perceived events for centring on the relations between analytical characteristics of the situations. The assumption advanced by the designers of this technology based learning environment is that this cognitive treatment of the situations is a possible precursor of a quantitative treatment implying of the expressed physical dimensions in a formal way. This aspect is partially valided by the observations reported in the specific context of the study (experimental activities preceed the work with the educational software).

4.4 Construction of a conceptual map in different contexts of cooperation – students in psychology (3rd year of university)

(Aurélie Lainé, Annick Weil-Barais, University of Angers, France)

The aim of this study is to analyse the cooperative activity in different collaborative contexts. The version 0.93 of ModellingSpace has been used, thanks to the assistance brought by Vassilis Komis at the time of a mission in Angers in October 2003. The remote communication was established thanks to network Intranet of the university. The students were in separate rooms. The instruction which was given to them was not to leave their working station, without the agreement of the person in charge of the follow-up of the experimentation (Aurélie Lainé). In fact, the students could work in an autonomous way, after a short presentation of the interface of the software (approximately 5 minutes). This fact shows the adaptation of the software to students who are familiar with the usual burotic softwares (Word and excell in particular).

> **ModellingSpace instructions given to students**
> On the left-hand column, you have the abstract entities (right-angled, circles…) and on the column of right-hand side, you have the relations.
> To use an entity, ridges to slip it since the left-hand column towards the working area. With a double click, you can insert text and name the entity. When you have two or several entities, in the same way, ridges to slip the relation which you wish to use. You can also insert text in the relations, if need be. Connect the relation to the entities which you wish. If you add an entity and that you want to connect it with an already existing relation, click on the arrow of the relation, that allows you to connect X entities between them.
> To remove an entity or a relation, click on the blue cross in top on the left.
> To collaborate with your partner type your sentence in the zone of chat. Only one of the partners can use the working area, if the other partner wants to take the hand, it must require the key of the other partner.

4.4.1 Description of the study

4.4.1.1 The task : to construct a conceptual map starting from the reading of a scientific text

The task requested from the students is a task of production of a conceptual map starting from a text. The selected text is extracted from an encyclopaedic dictionary (*Vocabulaire de Sciences cognitives,* PUF, 1998, Intéraction, p. 214-217). On three pages, the text presents a synthesis relating to a concept little known by the students at this level of study. The concepts connected (indicated in capital letters in the original text) were withdrawn.

The task not being familiar for the students, information of about thirty minutes was given before (a week as a preliminary) on the basis of example reported in three scientific publications using several graphic representations.

4.4.1.2 Procedure

The realization of the task proceeded in two phases: an individual phase and a co-operative phase.

First of all the students were invited individually, during a working session where they were in the same room, to produce a conceptual map.

> Consign: "*Read carrefully the text we gave you. This text extracted from Vocabulaire of cognitive sciences tries to define a concept. From the informations contained in the text, you must build a conceptual map. You have free: you can carry out several tests, write on the text photocopied… the only constraint is that the conceptual map can be registered on the recto of the sheet been enclosing in this document. You can use it in the vertical or horizontal direction. Write lisiblement with a lead pencil.*
>
> ***You have two hours*** *to achieve the task requested.*
>
> *Taking into account the aims of the study, it is necessary to work individually. We thus ask you to not have any exchanges with the other students during the session of work.*
>
> *We engage so that your answers are treated in an anonymous and confidential way. Do not put your name on the sheet where you write the conceptual map. Thank you for your collaboration.* »

At the issue of this meeting, the students filled a sociometric questionnaire in order to be able to compose the dyads.

In the second time (one week after the first phase), the students are invited to cooperate in dyads, in order to produce a conceptual map which satisfy them both. They have photocopies of the individual productions and the initial text.

A third of the dyads works with ModellingSpace with only one computer by dyad (face to face cooperation) ; another third works with ModellingSpace on separate working stations (in different rooms) (distant cooperation). A control group is composed of dyads which work together without the software. The verbal exchanges between the dyads (face to face cooperation) are recorded by means of a digital tape recorder. The work of the dyads is distantly supervised by the person in charge of the follow-up of the experimentation, but she does not take share with the activities.

> Consign for the group "distant cooperation"
>
> « *You must build a conceptual map of the concept defined in the text which was given to you. You must cooperate in order to produce the best possible conceptual map. With this intention, you have at disposal a software which enables you to create entities and relations and to collaborate remotely. An initiation with the use of this software will be given to you. This initiation is in theory sufficient so that you can work in an autonomous way. However, if you encounter difficulties, we will intervene to help you to surmount them. Pay attention: we can only bring you technical assistances to allow you to collaborate.*
>
> *All that you make with this software is recorded and will be analyzed at ends of study and research, preserving your anonymity.*
>
> *We thank you for having agree to take part in this study.*
>
> *You have* **one hour** *to achieve the task requested.* »

Each group is composed of as many dyads maintaining affinitary relations (to the questionnaire sociometric, A stated to want to work with B and B stated to want to work with A) and not affinitary relations (A and B were not chosen mutually but none wished to want to exclude the other). The following table gives the distribution of the dyads by experimental groups.

	Face to face cooperation	Distant cooperation	Control group
Affinitary dyads	2	3	4
Non affinatary dyads	4	2	2
total	6	5	6

4.4.1.3 Population

Students in psychology, third year of study.

4.4.1.4 General assomption

The use of ModellingSpace helps the students to release and structure the information contained in texts and to adopt a reflexive attitude compared to those who just use paper and pencil.

The students who use ModellingSpace would elaborate richer cognitive map and would have a more reflexive mental activity (awakening and clarification of the concepts and their relations), specially when the students communicate via the chat. Indeed, taking into account the fact that the written communication is more constraining than the oral communication, we suppose that the students who cooperate by means of the chat will have more exchange about contents of the text that those which discuss face to face.

4.4.2 Data analysis

Two sorts of data are analysed : the conceptual map and the verbal interaction between students.

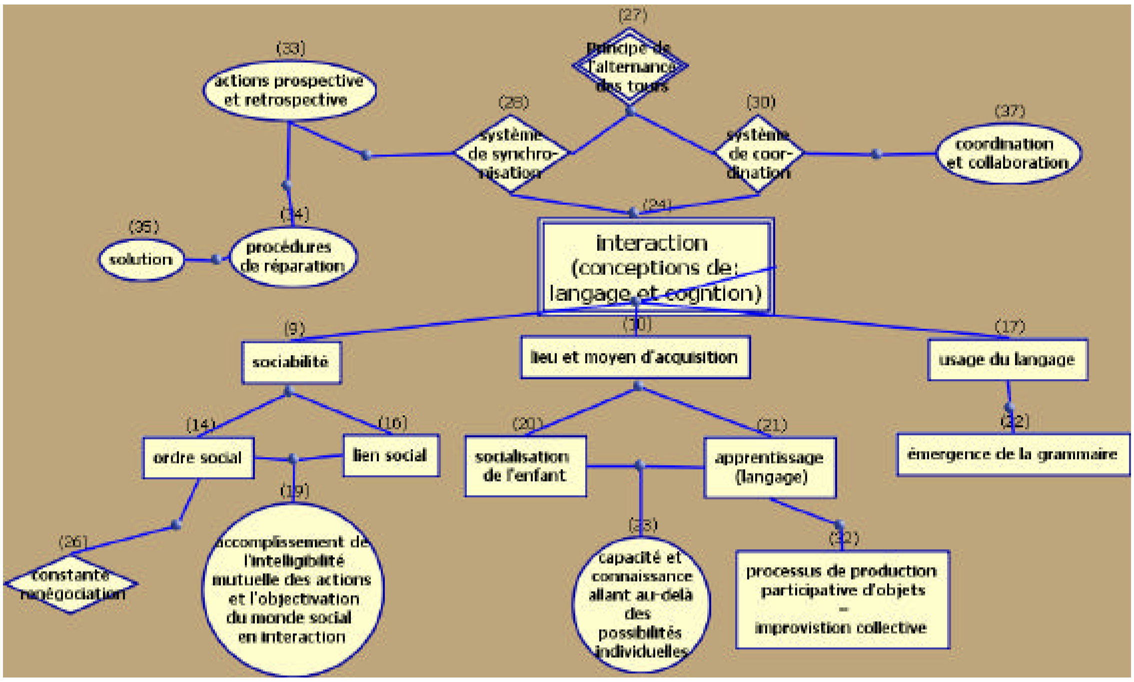
4.4.2.1 Conceptual maps

Several criteria of analysis have been considered :

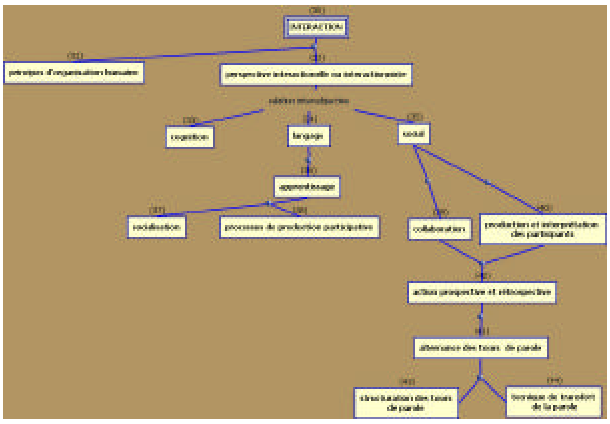
- the number of conceptual entities;
- the number of central concepts;
- the number of concepts related to the components of the interaction;
- the number of concepts related to the functions of interaction (social, cognitive, communicational, etc.);
- the number of links between concepts;
- the structure of the conceptual network (five structures revealing various degrees of structuring were identified);
- the graphic differentiation of the concepts;
- the graphic differentiation of the links between concepts.

These different criteria of analysis are supposed to evaluate the quality of the conceptual maps. The taking into account of these various criteria allows to class the conceptual maps on a “rich "/"poor"continuum (cf examples hereafter).

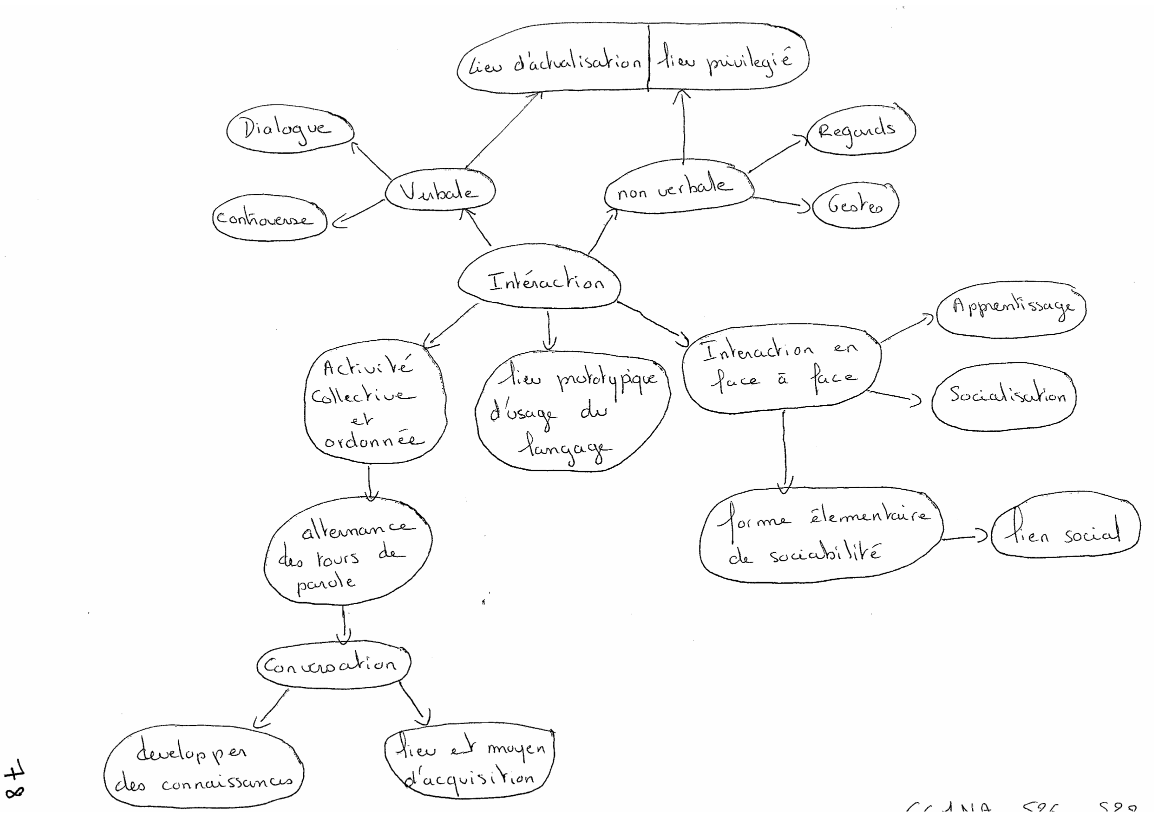
Examples of "rich" conceptual map (distant cooperation)



Examples of "poor" conceptual map (face to face cooperation)



Example of « middle » conceptual map (control group)



At the point where we are with the analyses, it appears that the maps produced in dyad are richer than alone. It is not surprising, since the superiority of the work in group was often shown. In addition, this cooperative work intervenes subsequently to an individual work on the same text.

It does not seem that the context of co-operation affect the quality of the productions, with the criteria which we have considered. However the students subjective feeling of success is better when they have work with ModellingSpace.

To explain the fact that overall there is no difference between the groups, one can advance the assumption that the level of expertise of the students is such that it is not improved by the use of a software as ModellingSpace. A study currently led with pupils of college (13 years old) using a similar task will permit to advance in the explanations.

4.4.2.2 Peer interaction

The analyses are currently in progress.

The oral interactions have been transcripted. The interaction are segmented in sequence and exchange, according to the model of conversational analysis (Kerbrat-Orecchioni, 1990) already used to analyse interactions in educationnal contexts (Danis, Schubauer-Leoni & Weil-Barais, 2003). For example, the quality of the exchange is evaluate by its extension (the number of interventions composing an exchange). The theme of the exchange are classified according to the nature of the student's interest : actions with MS, feelings, mental states, agreement, concepts.

Broadly, it appears that the oral dialogues are very mainly centered on the task (actions with MS and concepts) whatever the dyads (affinitary and not affinitary dyads). The written exchanges are extremely rich as well by the contents of the exchanges as by the structure of the exchanges. This is explained by the fact the interlocutors have the same workspace. Paradoxically, the exchanges are more successful in the written exchanges than in the oral exchanges where the topic of the exchange often escapes the partner. Written statements (chat) do not respect French strandard (cf example hereafter). The writing is often phonetic and uses the short cuts used in the texto sent by cellular telephone.

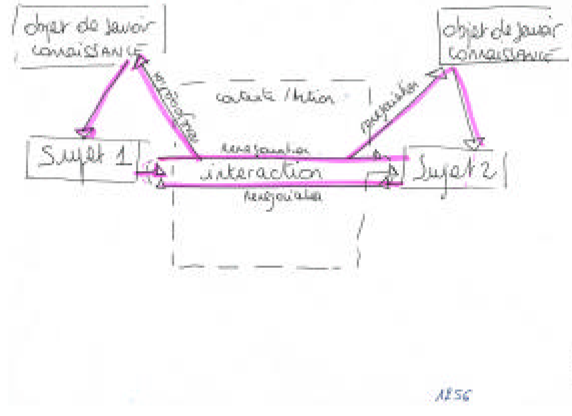
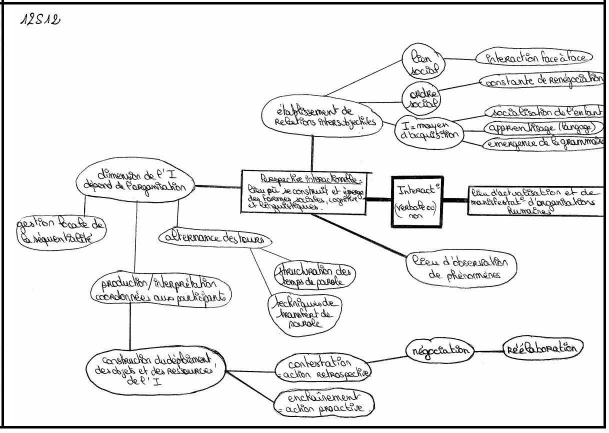
It seems tha the strategies employed by students vary according the interactional context. When the partners are together on the same workpost, they make much more actions and speak much. When they are separated, they plan better their activities. But finally, the conceptual maps constructed are nearly equivalent. So, we can consider that the distant context is more favorable to the learning of planning activities and cooperative attitude.

In a general way, we will stress the interest for the studies on cooperative work to have the analysis tools of activities integrated into the software. It appears as very usefull tools. So we now experiment the using of this tools in the context of the formation of students in psychology to analyse social interactions.

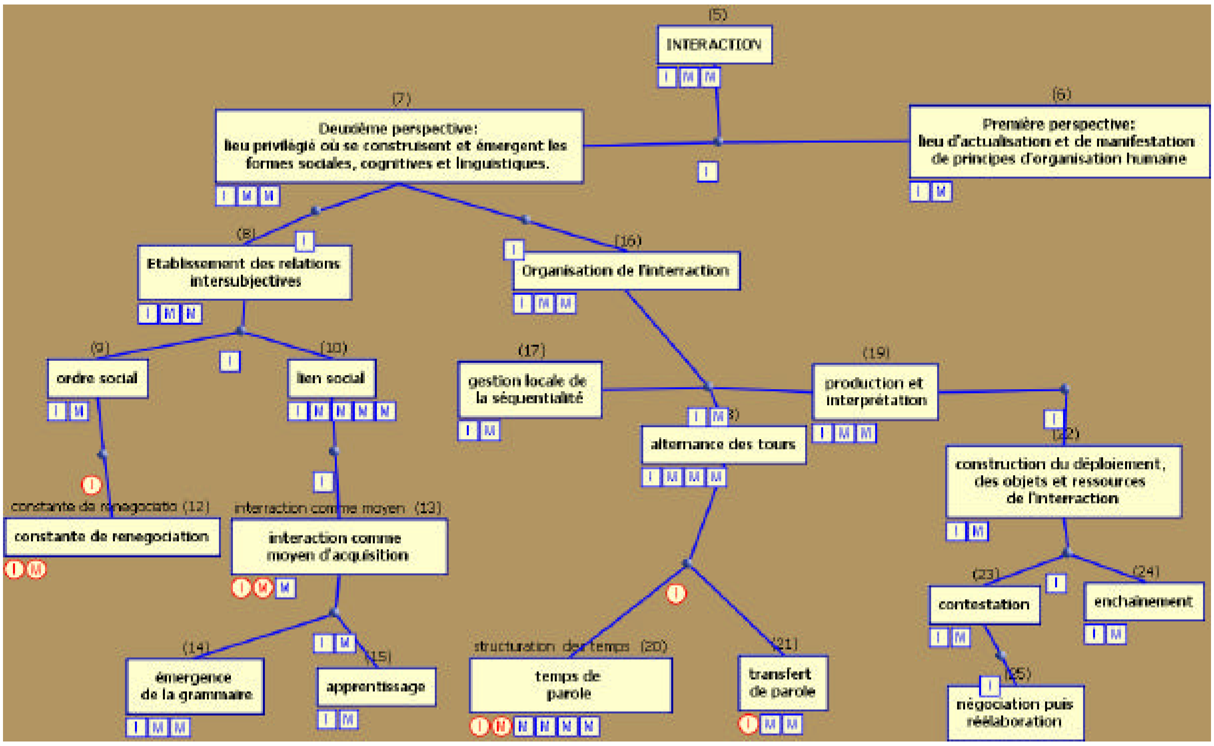
The research actually conducted in the lower secondary school will inform us on the pertinence of the software for the training of younger students to cooperate.

4.4.2.3 An example of affinitary dyad (distant cooperation with ModellingSpace)

DYADE 12G3AS6S12

Initial conceptual map of S6	Initial conceptual map of S12
	

Final conceptual map of the dyad



Key times

S6	00:17:57	21%
S12	01:07:05	78%

The beginning of the chat (1/3 of the interaction)

[S6] bonjour	[S6] hello
[S12] bonjour	[S12] hello
[S6] tu peux commencer si tu veux	[S6] you can start if you want
[S12] Ok si té dacord on va placer interaction au centre	[S12] Ok if you agree one will place interaction in the center
[S6] oui	[S6] yes
[S12] pAR RAPPORT AU TEXTE JAV2 COMPRI Q 2 Perspectiv existé	[S12] compared to the text that I had understood two prospects exist
[S6] laisse moi 2 minutes pour regarder ta carte je t'envoi un message des que j'ai termine	[S6] leaves me 2 minutes to look at your chart: I send a message to you as soon as I finished
[S12] ok	[S12] ok
[S12] Je pense qu'il faut reprendre avec le texte pour savoir si l'on a compri la même chose?	[S12] I think that it is necessary to begin again with the text to know if the same thing were included/understood?
[S6] comment ça deux perspectives mise à part ça ta carte me semble correct dans tout les cas c'est une carte conceptuelle je vais essayer de te dire ce que je pense au fur et à mesure mais garde la clef	[S6] how that two prospects put besides that your chart seems to me correct; in all the case it is a conceptual chart; I will try to say to you what I think progressively but guard the key
[S12] Donc tu ve q je reproduise ma carte?	[S12] Thus you want that I reproduce my chart?
[S6] j'avais pas vu ton message si tu veux on reprend le texte mais ça va prendre du temps comme tu veux	[S6] I had not seen your message if you want one takes again the text but that will take time as you want
[S12] 1er paragraph 2 perspectiv: Soit... soit... coresponde a mes 2 lien avec interaction	[S12] 1st paragraph 2 prospect: Either… or… corresponds to my 2 links with interaction
[S6] ok	[S6] ok
[S12] Ca ta va?	[S12] that suits you?
[S6] de l'interaction emergent les formes sociales, linguistique et cognitif: pour le cognitif ?	[S6] from interaction social forms, linguistics and cognitive emerge: for the cognitive one?
[S12] ????	[S12] ????
[S6] je suis en train de relire le texte en meme temps je regarde ta carte et je me melange un peu bref continu sur l'etablissement des relations inter	[S6] I am reading again the text at the same time I look at your chart and I mix a little; in short continues on the establishment of the relations inter
[S12] C le lien social ordr social et moy dacquisition qui te dérange?	[S12] It is the social bond, social and average order of acquisition which disturb you?
[S6] oui	[S6] yes
[S12] moi aussi	[S12] me too
[S12] ta retrouvé dans le texte ou sa se situe	[S12] you found in the text or that is located
[S6] non je cherche	[S6] not I seek
[S12] dédut colone droite 1ér feuil	[S12] right column beginning first sheet
[S6] j'ai trouvé je lis	[S6] I found I read
[S6] tu peux pas virer le lien social ou le mettre sur le fleche de l'orde sociale	[S6] you cannot transfer the social bond or put it on the arrow of social nature
[S6] entre les relation inter et l'ordre sociale	[S6] between the relations inter and the social order

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5 EVALUATION OF MODELLINGSPACE LEARNING ENVIRONMENT IN REAL SCHOOL CONTEXTS

(Learning Technology and Educational Engineering Laboratory, University of the Aegean)

5.1 Overview of case studies report, related to the implementation of ModellingSpace learning environment in real school contexts

A number of case studies related to implementation of ModellingSpace in school contexts were conducted in schools under the responsibility of the University of the Aegean.

The case studies report presented into the next sections concern the following:

1. Class of a Primary school (12 years old students), working with semiquantitative relations and object-oriented entities.

Learning Activities concerns problems with proportionality (Mathematics).

Main Scientific Concepts involved: time, volume of a liquid in a recipient, flow/flux. Experimental situation with real objects in conjunction with modeling through ModellingSpace, Duration: three sessions of 90 minutes. [3 x 45min].

The case study report presents results on the following:

(g) The possibility of young children to express themselves via ModellingSpace semantics concerning semiquantitative relations, their difficulties in some aspects, & specific points where ModellingSpace could create misconception to children when working during a few number of sessions,

(h) children' evolution on reasoning and expressing relations of proportionality,

(i) children' evolution in using related concepts.

2. Class of a Lower secondary school (14 years old students), working with semiquantitative relations and object-oriented entities.

Learning Activities concerns problems with proportionality (Mathematics).

Scientific Concepts involved: time, volume of a liquid in a recipient, flow/flux.

Experimental situation with real objects in conjunction with modeling through ModellingSpace. Duration: two sessions of 90 minutes. [2 x 45min].

The case study report presents research results on the following:

(g) the possibility of students 14 years old to express themselves via ModellingSpace semantics, & their difficulties in some aspects,

(h) students' evolution on reasoning and expressing relations of proportionality,

(i) students' evolution in using related concepts

3. Class of a Primary school (12 years old students), working (a) with semiquantitative relations and object-oriented entities, & (b) with concept maps.

Learning Activities concerns <u>Chemistry</u> problems related to Solutions.

Main involved concepts: => condensation & dilution of a solution, compounds, homogeneity of a solution).

Combination of real objects' Experimental situation with modeling through ModellingSpace (concept maps- models with semiquantitative relations – concept maps).

Duration: six teaching sessions of 45 minutes [6x 45min].

The Case study report presents research results on the following:

(g) The possibility of young children (12 years old) to be easily familiar with ModellingSpace semantics of concept maps creation and simple aspects of semiquantitative relations (implicating only two variables each time),

(h) the appropriateness of ModellingSpace environment and learning activities to support misconceptions appearance and then the evolution on scientific concepts construction,

(i) the ability of young students to work with concept maps and to progress via the whole set of learning activities related session.

4. Class of a Lower Secondary school (15 years old) working with (a) semiquantitative relations and object oriented entities & (b) quantitative relations.

Learning Activities concerns Physics problems related to Kinematics.

Main involved concepts => position, time, velocity, acceleration.

Familiar problems to be modeled via semiquantitative relations expressions and then quantitative ones.

4.1. Pilot study focusing on the role of object-oriented entities, their simulation and their effect in learning physics concepts.

The case study report presents research results on the effectiveness of a specific category of entities (the object-oriented entities with specific representation of motion variables), to make appear students misconceptions related to specific concepts (position, velocity as vectorial concepts) as well as their appropriateness to make students ideas evolve to the scientific ones.

4.2. Global results, from a 12 hours teaching unit, on modeling in physics, using semiquantitative and quantitative relations:

The case study report presents research results on the following:

(A) (a) understanding of representations: table of values and graphs , (b) modeling process, (c) teaching strategies

(B) The contribution of MS environment and worksheets on learning concerning: (a) the construction of a structured network of concepts, (b) the relations among specific concepts, (c) the distinction among independent and dependent variable, (d) the relation of proportionality, (e) the notion of a 'constant variable', (f) misconceptions and their evolution related to the concept of velocity, and the concept of position (g) students difficulties when they construct algebraic models.

5. Four Classes of a Lower & Higher Secondary school: Teaching & Learning during synchronous collaborative modelling through ModellingSpace among co-located students.

Unified case studies report taking into account, teaching sessions in four different classes, and three different schools:

15 years old students (two classes & teachers in two different schools)

16 years old students in a technical high school

17 years old students in a technical high school

The Learning activities concerned mostly mathematics.

Students were involved in quantitative models, and in the use of these models in order to answer related questions.

Duration: eight teaching sessions: [8x 45 minutes]

The Case studies' reports related to collaborative learning present research results on the following:

15. The tools that support teachers for collaborative learning activities implementation and management during (online) and after (offline) the collaboration sessions.

16. The meaning, the quality, and the strategies of synchronous collaborative problem solving through MS for the specific modes of use.

17. The comparison of the modes of use.

18. The motivation of students to work on collaborative modelling activities

19. The students and teachers point of view for the learning value of collocated collaborative problem solving using MS.

20. The study of teachers' interventions and their consequences when they participate/supervise or guide the synchronous collaboration between two students.

21. Students' ideas about models and modelling after ModellingSpace based collaborative activities

5.2 Class of 12 years old students creating models involving semiquantitative relations and object-oriented entities.

[authors, researchers: George Tzortzakakis, Christos Mitsoullis, LTEE lab/Aegean)

5.2.1 Research Questions

(a) Young students can express themselves with the “semiquantitative relations”? Interaction with MS, could support them to a related learning evolution ?

(b) Young students have difficulties with concepts intervening during interaction with MS semiquantitative relations ?

(c) Young students meet difficulties with MS that could de-motivate them for their involvement to related learning activities?

(d) Is it possible to implement MS environment into a typical school without any tradition to ICTs use, with a very low tradition to innovative (external) projects, with a teacher applying traditional teaching approaches?

5.2.2 Information related to schools and teachers

(a) Table of School presentation

School Names	Schools	Classroom	Number of pupils	Teachers' name	Disciplines taught
1st Ialysos Primary School	*Primary School*	Classroom 1 : *ST2* *(12 years old)*	22	Xaris Papakyriakou	Teacher of Primary Education (all subjects)

(b) Information related to school

- *General information related to school identity.*

  It is a small primary school of a village located near to the capital of the Rhodes Island. The school community consists from 10 teachers, and 6 classes of 150 students (7 –12 years old).

- *Does the school have a computer room? Which is the number of computers for pupils? Which are the characteristics of computers (year, power, internet, CD-Rom)?*

  A small computer room with 10 PCs & internet connection, for the whole school.

- *Which is the teaching part of ICTs (duration, disciplines taught using informatic)?*

During the typical program in 2003, there were not any courses related to ICTs. Only one teacher over the 10 teachers of this school had used ICTs during its teaching. This teacher used to use ICT mainly for courses related to the subject matter of language (via Word).

Thus, this school can be considered, as a traditional school that has not experiences on ICTs use, or integration of ICTs in every day courses.

- *Did the school already take part in research projects?*

  During the 5 last years, the school have taken part in a pilot program concerning culture in primary education

(c) Information related to teacher

- *Which are the software usually used by the teacher?*

(1) Word for development of written expression, (2) commercial demonstration-electronic books, & associated with drill & practice, related to: "Geography of the Globe", "100 years Olympic games", "The revolution of 1821 into the museums of Greece", " The music instruments"

- *Did the professor participate already in research projects?*

The teacher participated to a pilot project related to culture in primary education

- *Teacher profile:*

The teacher has an experience of 20 years in primary school. He feels specialist more on subject matter related to language, culture, etc., rather than to mathematics, & physics sciences. He likes to be implicated to research projects and to the use of computers in order to change a little its every day professional life.

- *Teacher opinion related to the main reason of MS choice, and the role of modelling:*

The initial opinion of teacher was that the main reason justifying the use of MS is the : (a) the interests that students may express for the software, and (b) its own interest for this experience (and not the innovative character of the software or its possibility to be adapted to the curricula).

Concerning the role of modelling into the curricula: The teacher concerns that modelling must have a secondary role (and not a primary one). It has to be mentioned that even if it teaches all the main subject matters, it has a particular interest for the subject of language (and not these of mathematics or sciences).

5.2.3 Learning Activity

- **Name of activity** : "Supplying a Container with wine " [See Annexe x]
- **Questions or assumptions related to the activity content and conception:**

  Assumptions: Appropriate activity for young student, given that give rises to a real phenomenon, that students could observe into the class (and not a phenomenon analysed only mentally). It contains three main parts:

(a) a first part during which teacher and students work on a real experiment &

(b) a second part during which students create and explore a model through MS.

(c) the third and final part is dedicated to a global written report prepared by each group of students. Students refer on what they learned, on what were their difficulties, and they present the constructed model.

Activity Purpose: Activity that involve students to model through semiquantitative relations involving three variables.

- **Authors of the Activity:** The initial entities and scenario was conceived by Vassilis Komis, Assistant Professor (Univ. of Patras). The actual version of the scenario, associating the real experimental activity with the activity through MS, was introduced and prepared by George Tzortzakakis (Young Researcher, LTEE lab, Aegean University) & Xaris Papakyriakou, Primary Education Teacher, Ialysos, Rhodes, Greece.

Activity Description :

- ***Subject****:* Mathematics,
- ***Topic***: proportionality & graphs,
- ***Activity mode:*** Experimental situation, *& a model construction and model exploration mode*
- ***Activity central topic:*** Learning activity, inciting the study of "variables' and their covariation in a situation where, a container is filled with a liquid.

- ***Activity Approach considered:***
  (1) A problem is introduced and initially explored by a real-objects experimental situation. Then in order to be more extensively studied, students are introduced to the MS environment (in order to be able to do predictions),
  (2) Initial activity, situation were we have a problem and then we will introduce MS, because give us some additional possibilities (and not as a nice technological tool)
  (3) Simple written Report at then end
- ***Related to the questions and the exercises given to the pupils*****:**
  (I) During the first activity sheet the questions: (a) guide students to identify factors affecting the phenomenon, (b) Observe, and think about the co-variation between factors (variables), (c) Create a value table from experimental data.
  (II) During the second activity-sheet the questions guide students to: (d) Select entities (e) express relations, (f) observe representations (barcharts & graphs), in order to validate the model and compare experimental data representations with model data representations
- ***Justification of the choice of the activity compared to the research questions*****:**

  Initial activity with MS, allowing student to study a simple phenomenon.

- **Choice of MS tools :** *to justify the choice of entities, relations, models compared to the questions.*

  (a) Entities: object oriented entities (barel, chronometer),

  (b) Relations : semiquantitative ones of direct proportionality and inverse proportionality,

  (c) Models : object oriented models, with maximum three variables, and semiquantitative relations,

  (d) Graphs: Barcharts, and then graphs.

5.2.4 Context of Study

- **School :** Primary school, Ialysos, Rhodes. A primary school, in a village of Rhodes Island, where there is a low quality PC-lab, and only one teacher has a low experience with the use of ICTs. The teacher with the same classroom had already use PCs for activities with Word (6 sessions), for improving written expression purposes.
- **Classroom :** 6^{th} Grade (11-12 years old)
- **Number of pupils** : 22 students
- **Activity** : Activity 1
- **Duration of sequence** : 3,5 school class hours
- **Place (class, computer room):** Computer Room
- **Questions or assumptions compared to the context of the situation:** Normal Classroom of a primary school, with the whole class and the real teacher. So, implementation of the MS whole learning environment in real school conditions.
- **Role of the teacher**:

The teacher leads the activity and asks questions to the students, in order to verify understanding. The initial guidelines was that the teacher must avoid giving direct information to the students, related to implicated concepts & process, except information & guidelines related to MS interface.

Role of researcher : The researcher is into the class, in order to:

(a) Assure the collection of data,

(b) Assist teacher to any technical problem with MS

(c) Eventually, assisting group of students that may have difficulties in the manipulation of MS

(d) Assist teachers later, during the meta-analysis of teacher pedagogical strategies applied during the class. There are some sessions during which the teachers with the research observe the video-tape of the teaching session.

- **Context of situation:** *collective or individual…to justify the choice of the context compared to the questions.*

  Normal Classroom of a primary school, with the whole class and the real teacher; students working per groups of two students (two students side by side, in face of a PC)

- **Description of the context :**

  - Into the class exist: the PC of the Teacher as well as a Data Display (allowing the facilitate the demonstration of the MS main and basic features, as well as a model that is to be discussed by all the class, if needed)

  -A Video camera is located at the back part of the room.

Teaching Sessions:

Sessions	Duration	Aim	topic
1	1, 5 h (2 x 45 min)	Experimentatal situation Familiarisation with MS environment, using the 1st worksheet	Study of relations among variables that influence the phenomenon of a tap filling a recipient.
2	1	Continuation of the learning activity	
3	1	Final discussions in class, & Written Report preparation	

Table 1: Sessions Plan in 6th grade students, in traditional Primary School of Ialysos

1st Session: i) Start from a real experiment, think about factors and taking measurements

2nd Session: ii) Then, through MS create models involving Semi-Quantitative relations, Graphs & Tables

3rd Session: iii) Finally, Students write a report on the model created

.

5.2.5 Population

- **Number of pupils** : 22
- **Age of pupils** : 11-12 years old
- **Other information**: 5 high level students, 15 middle level students, 7 low level students (teacher's indications)

- **Organisation of Students' groups:** -20 student work in peers of 2 students. Group formation: mixed ability groups indicated by the teacher.
- **Students experience with ICTs:** Low previous experience with ICTs (mainly word processor use, and drill and practice educational software.)

5.2.6 Data collection

- Material used to collect data
    - o Video –Camera: a camera covering the whole class, but focused on teacher.
    - o Logfiles of each group of students, interactions
    - o Models of students
    - o Printed Activity-worksheets of students
    - o Electronic form of written report of students, at the end of the session
    - o Video-tape of the meta-analysis sessions between teacher & researcher (sessions where teacher & researcher watch on the video of the teaching session)
    - o Teachers written report after the end of learning activity sessions

- Type of data used for the results analysis*:* (a) answers on the students' printed worksheets, (b) elecronic form of students report on their modelling activity, (c) teachers reports on the teaching process.

5.2.7 Data analysis

5.2.7.1 What were the main difficulties of students that were revealed during teaching sessions?

From the teacher written report at the end of teaching sessions, we combine the data related to: (a) the main initial learning objectives, (b) the aspects that seemed to be more constructive for students, (c) the difficulties that students present that may be were not expected.

<u>(a) The Main initial learning objectives were the following:</u>

- ⇨ take measures during a real experiment
- ⇨ identify and name variables orally
- ⇨ identify and name entities and variables in the ModellingSpace environment
- ⇨ Reasoning and expression in terms of proportionnality
- ⇨ Study of regularities in a table of variables' values

- ⇨ Read a Graph
- ⇨ Distinguish an independent variable from a dependent one.

(b) What was mostly discussed (aspects that children have learnt about):

During the three sessions, students have reasoned and they were involved in constructive discussions mainly on the following aspects:

- the factors that influence the phenomenon and the distinction among them[the variable of time, the variable of flow, the distinction between flow and volume of the liquid, the distinction between the volume of the water filling the recipient and the maximum volume of the recipient]
- Generalisation, extension of similar nature reasoning in slightly different objects that may be involved in the same phenomenon [recognize the similarity among the various recipients // MS includes at least three 'different' object oriented entities that represent a recipient]
- Study of regularities in a table of variable's values (the meaning of proportionality between two variables and the covariance of their values)
- Read & study a number of different data representations (simulation, table of value, and bar-chart) and try to reach inferences

(c) Main Difficulties of students:

All the students of the class have difficulties on the following:

(1.) To conclude about relations, when the simulation's behavior is not interpreted well. The incapacity to interpret the simulation's behavior leads to ad hoc uses of various others relations /variables

Children had to observe the algebraic values of each variable, in order to examine the compatibility among the values of variables, so as the expected simulation is produced. It is not easy for so young students, to reason in a semiquantitative way (in terms of relations), and in the same time to have to think in a strong quantitative way, in order to see the simulation

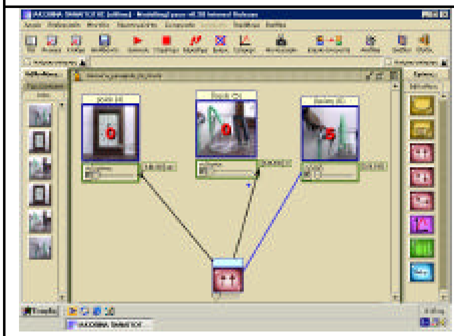
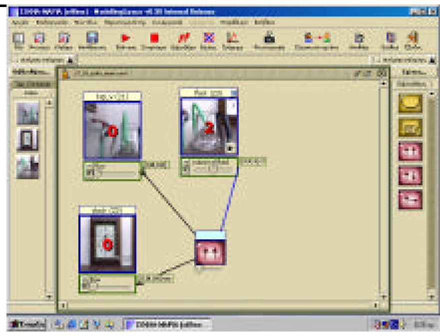
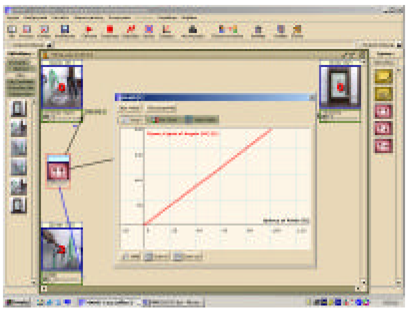
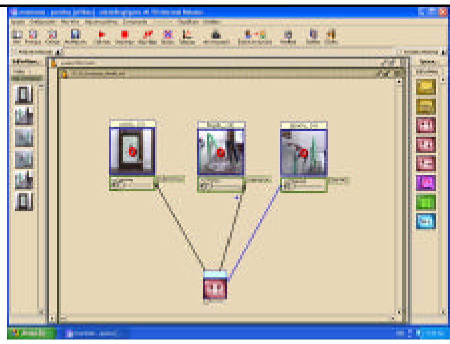
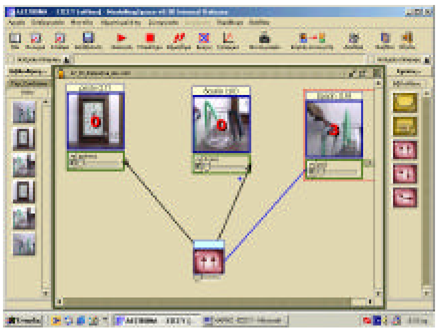
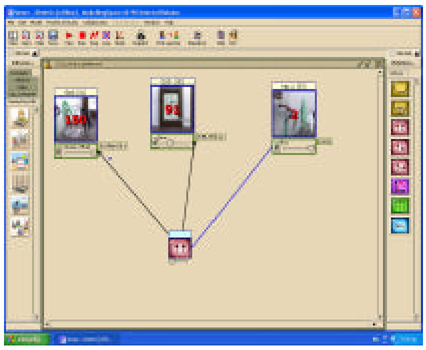
(2.) The difficulty to understand the meaning of the constant of a proportionality, and its correspondence with the physical status of this constant. (the flow of tap is the constant into the relation of the proportionality between time and volume of the water into the recipient. Students must link this variable to the relation of proportionality. This indication is not a natural way of thinking for children).

(3.) The distinction between Independent and dependent variable. The discussion on this distinction has to be continued with a number of examples during a range of different learning activities

<u>(d) Students' models and their possibility to create models.</u>

All students reach to create an appropriate model at the end of the 2nd session. 4 groups among the 10 had to be guided either from the other groups of students or from the teacher.

It is to be noted that in the beginning some of the students have used the entity barrel, while others the entity 'coffee recipient'. At the end all the students preferred to take the same entity coffee recipient, justifying that it is more similar to the initial experimentation with real objects into the class. [even if in the meanwhile, a discussion was contacted that the two models are exactly the same]

	
G1	G2
	
G3 model	G4 model
 G5 model	 G6 model

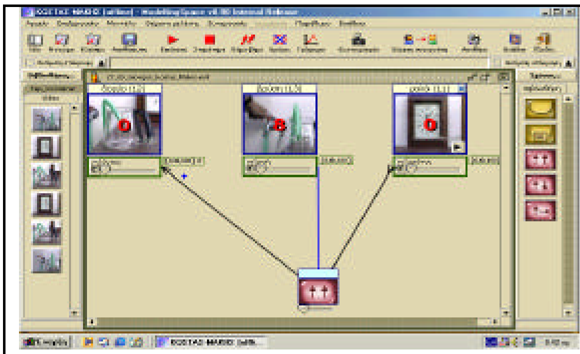
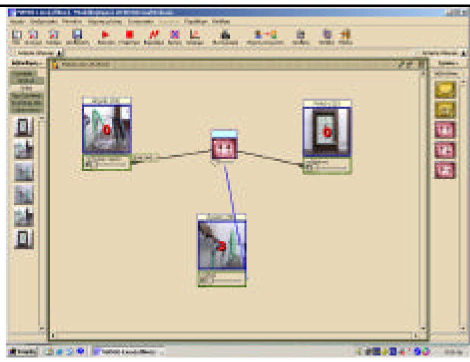
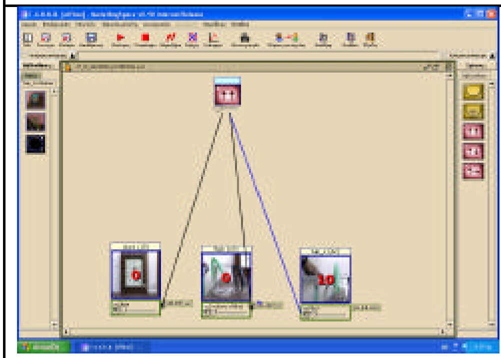
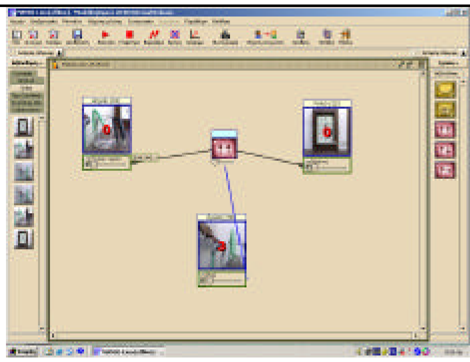
	
G7 model	G8 model
	
G9 model	G10 model

Table 1. G1-G10 Groups of students (12 years old) final models of the 'recipient tap activity'

5.2.7.2 Students' point of view on what they have learned, their difficulties, and the eventual difficulty of ModellingSpace use.

At the end of the three sessions, the students (12 years old) are asked to write a report (a) presenting and justifying their model, (b) explaining what they consider to have learnt and (c) if they had difficulties during model creation.

The report was prepared in electronic mode (via the wordprocessor MS Word). Students presenting the model with a screen-image of their model (printscreen action, and inserting into the word), and some of them justified the appropriateness of their model, by presenting one or more screens with the table of value and/or the graph (t->V).

(a) What students consider that they have learnt?

Table 2, presents data from the students' written expressions taken by the written reports produced by each group of students (G1-G10).

G1	"The table of values helps us to see the progressive increase of the values. We can make a graph."

G2	"The table of values helped us understand how proportionality works."
G3	"With this model we try to understand better the problems of proportionality. Moreover, in order to understand how time, volume and the tap's constant flow are linked. In order to make our model we used the above pictures. We linked these pictures with the relation of proportionality. Our goal was to create the correct model. To this end we had to link correctly the relation with the pictures, to set the correct values, so that our model works well.
G4	"We learnt to create tables of values, bar charts and graphs."
G5	"The table of values helps us understand by how many times does time increase with volume and helps us understand the relationships between the pictures. It also helps us understand if the values are direct or inverse proportional."
G6	"This model was created so that we can find out that we can solve mathematical problems using tables of values and modern means
G7	"Every time we entered the program we learnt something new. We learned to create table of values, to run a model and to make a graph."
G8	"We ventured out of our familiar classroom in order to learn how to create a model.
G8	--
G9	--

Table 2. Data on what students believe that they have learnt during model process

Data Analysis:

To the general question '"what you feel you have learnt?", there appeared the following categories of answers, related to the 'specific topic' that they consider that they have learnt about:

N/A	Categories of students' answers	Number of groups
1	on proportionality and factors are linked	two groups, (G2. G3)
2	Models' creation in general	one group (G8)
3	the mathematical problems, in general	one group (G6)
4.	table of values and graphs.	six groups, (G1, G2, G4, G5, G6, G7)

Table 3. Categories of students answers' content on "what they learnt?"

Discussion on Results:

On the question, what they feel that they have learnt, most group of students mention the creation of tables of values and graphs. It is considering, that was influenced by:

- the initial experimental situation,
- the possibility that they had to study the relation of values into the table,
- the unique possibility for these group of students to study these graphs.

This aspect was the nearest to their previous learning experiences.

It is to be mentioned, that none mentioned (a) "independent & dependent variable", (b) methodological evidences on how to explore the interrelation among variables, (c) the concepts used (volume, flow, time).

It is also to be highlighted some expressions of children related to the conceptualisation of their actions. "in order to make our model we used the above pictures." "We linked these pictures with the relation of proportionality"G3. The general expression of the variables with the name of 'pictures', is to be taken into account by teachers, even if we have not met it in other group or individual student. It is a point that may cause new misconceptions to young students.

(b) What were the difficulties on model creation according students?

Table 4, presents data from the students' written expressions taken by the written reports produced by each group of students (G1-G10).

G1	"In the beginning we had difficulties, then it was exciting"
G2	"We tried to prevent the beaker from overflowing, by putting what we considered as the *correct numbers* for the current and maximum values. After some attempts we succeeded."
G3	--
G4	"One of the difficulties we met was that we could not *link the relations* correctly."
G5	"Of course, we also had some difficulties. We had a hard time finding the *right values* so that our model works well."
G6	"When we created the model, we faced some problems. These were: we found difficult *to link* time with the volume of water entering a barrel. Also we found difficult the differences of the model. One more problem *was not to let the barrel* overflow. But we made it in the end."
G7	"I had some difficulties *linking* models and relations."
G8	--
G9	"We tried a lot to *account the correct numbers* for the current and maximum values."
G10	"Our group hadn't really difficulties"

Table 4. Data on what were the difficulties according students

Results presentation and discussion:

We can distinguish three main categories of students' answers:

N/A	Categories of students' answers	Number of groups

(1)	difficulties on linking the relations correctly	Three groups [G4, G6, G7]
(2)	on considering the correct values in order to see the simulation.	Four groups [G2, G5, G6, G9]
(3)	No difficulties mentioned or no answer	[G1,G3, G8, G10]

Table 5. Categorie s of students answers on 'which were the difficulties?'

We consider that the mentioned difficulty (1), it may consists on the difficulty of linking the concepts with the right order (independent and dependent variable), as well as on the difficulty to relate the physical variable that correspond to the constant of the relation of the proportionality, and to proceed to link this entity (flow of tap) with the relation.

Taking into account the notes of observations of the researcher, as well as the video recording all the groups met the similar difficulties, in a different degree. For some groups was easer to surpass them, and for some others was harder. [4 over 10 groups]

(c) Is it difficult to work with MS (according students' point of view)?

G1	*We faced some difficulties at the start.* We could not link the pictures with the relations.
G2	When we went in and sat down, *everything looked unfamiliar. In a few days however, we began to understand.* At the start, we could not understand how we could link the relations with the objects.
G3	----
G4	*I do not believe in the great difficulty of the programme*. We believe that this programme with a little more hard work, will perfect itself and will reach the level of MICROSOFT programmes."
G5	When we first came here, *everything appeared very difficult*, but in the end we like the programme very much.
G6	The difficulties we met were not very many. *The programme was complex* but pleasant and entertaining. Now, I think that it seems to me easy and exhilarating.
G7	It was appeared strange to me, at the first time, but then it was much more interesting to work with this, that the every day courses.
G8	------
G9	"At the beginning we found it hard, but as time goes by we understood it.
G10	-----

Table 6. Students' answers on "if it is difficult to use ModellingSpace?"

Results discussion:

The children' notes give us the impression that almost all children considered at the beginning the interaction with MS as difficult.

- Five over 8 groups used words with a meaning that the environment was difficult or very difficult (words such as: difficult, hard, complex, strange), at least in the beginning.
- Three groups used softer expressions (such as: unfamiliar, some difficulties).

We believe that this 'difficulty' is not only due to the unfamiliarity with the environment, but reflects the fact that during this kind of problems, children was moving to face directly two main obstacles:

(a) distinction between dependent & independent variables,

(b) the need to pass directly to quantitative reasoning, (in case that the simulation was not running) in order to account the appropriate combination of values in order to make model run. This second difficulty was even the most important.

It is to be mentioned, that even if students had these difficulties, they have not lost their interest and their motivation to continue work with MS.

5.2.7.3 Students evolution related to expressions of proportionality, and the identified factors affecting the phenomenon under study

It is interesting to examine how students express themselves before working with MS, in order to get an idea of their initial conceptualization, as well as to study their evolution, as it is revealed by the written expressions of each group of students.

The data that are presented and analysed in the following, derive from the answers and notes of each group of student to the paper worksheets that were given to students during the 1st & 2nd sessions.

More specifically, from these sources of data, we analyse: (a) the factors affecting the phenomenon under study that they identify, the degree of appropriate expressions, the expressions of proportionality]

1. What factors –variables students identify when they study a simple phenomenon (before working with MS)?

During the experimental activity and before starting to work with MS, students answered the following question:

"*We have a tap that supplies with water a barrel. Where does the volume of the water into the barrel depends on*?"

1.	G1: It is depending from the quantity of water that the tap drops.
2.	G2: The volume of the water depends from the tap and from the volume of the barrel

3.	G3: The volume of the water depends from how large is the barrel.
4.	G4: From the water flowing from the tap, from how much water gives the tap, from how much time the tap is open.
5.	G5: The volume depends from how big is the barrel and the quantity of the water flowing from the tap.
6.	G6: From the barrel capacity
7.	G7: From how much water the barrel can contain
8.	G8: The volume of the water depends from barrel. And from how much water the tap gives.
9.	G9: From the quantity of the water that tap gives.
10.	G10: From how much water we will flow to the barrel

Table 7. Students answers related to the factors that influence a dependent variable (Before MS)

Focusing at this moment on if students have identified and have taken into account all the main variables, we analyse the above answers on the three main factors that were mentioned: time, a factor related to the tap (the flow, or the volume of the water from the tap, or just a mention to the tap), and the total volume of the barrel.

	Time	flow of tap or just only tap or Volume of tap water	total volume or shape of the recipient.
G1		+	
G2		+	+
G3			+
G4	+	+	
G5		+	+
G6			+
G7			+
G8		+	+
G9		+	
G10		+	

Table 8. Analysis of Answers related to the factors that influence the volume of the liquid filling a recipient

? he table 8 presents: (a) if students have identified that the time is a factor or variable that has to be taken into account, (b) if they mention a variable related with the tap (the flow of the tap, the volume of the tap water, or even just the tap), (c) the total volume of the recipient, (d) the volume of the water into the barrel.

- ⇨ Only one group (G4), has answered correctly, taking into account the two main factors (time & flow of tap).
- ⇨ Most of groups (six) were concentrated to the maximum value of the liquid volume (depending from the recipient shape).
- ⇨ According to three groups, the only factor is the recipient shape.

Taking into account the students answers (table 7), & and their categorization (table8), we conclude that in the beginning, students had not conceptualized the concept of 'flow', while the time intervenes in an indirect and non distinct way.

2. Expressions of proportionality at the beginning and at the end of modelling activity through MS

When students started to model the phenomenon (inserting entities and specifying variables) through ModellingSpace environment, the following question was presented to them via the printed worksheet:

" ***If we keep the flow of the tap constant where does the volume of the water into the recipient depend on, and how***?"

Gn	**Answer of the corresponding group (extracted from the group worksheet)**
G1	As longer is the time that we have, as more the volume of the water»
G2	As longer is the time, as more the water. As less is the time as less the water
G3	on the time that goes by
G4	As time goes by, as the barrel will be filled
G5	By the time that the tap flows
G6	From how much water flows from the tap
G7	As longer is the time as faster the barrel will be filled
G8	As more hours the tap is open, as more the tap will fill the barrel, while as less hours as less water quantity will be into the barrel.
G9	From the duration of time
G10	As much time we have, as more the barrel will be filled

Table 9. Students' answers expressing proportionality at the beginning of modeling activity

From the students' answers (presented into the table 9), we can identify: (a) the answers that mention the factor of time, (b) the answers that express a relation of proportionality or a similar one. The categorization of the students answers according to these two aspects is presented to the table 10.

Code of each students' group	**Relation of proportionality**	**Expression of the factor 'time'**
G1	+	+
G2	+	+
G3		+
G4	+	+
G5		+
G6		
G7	+	+
G8	+	+
G9		+
G10	+	+
?otal	**6**	**9**

Table 10. Answers categories related to the expression of a relation of co-variation between two factors/variables (proportionality)

From the table 10, we can refer that:

(a) almost all group of students (except G6) answered identifying the factor of time

(b) Six groups of students expressed a relation of proportionality (with slightly different ways). We considered worthwhile to present them, in order to get an idea of the range of related expressions of children in that age.

At the end of the second session, after have created and validated their models, students were invited to answer on the worksheet, a similar question:

In what way do you think that time with volume of the water that enters the barrel are connected, (considering that the tap flow remains constant)?

	Before working with MS	**After working with MS**
G1	As longer is the time that we have, as more the volume of the water»	As more is the time as more the barrel is filling
G2	As longer is the time, as more the water. As less is the time as less the water	As more time we dispose as more water volume we will have into the barrel
G3	on the time that goes by	¨as the time goes by, as the volume of the water increases
G4	As time goes by, as the barrel will be filled	As more water the tap gives as more water will fill the barrel
G5	By the time that the tap flows	As more hours the tap drops as more volume we will have ¨
G6	From how much water flows from the tap	¨As the time increases and the flow of the

		tap remains constant, as much the volume of the water into the barrel increases
G7	As longer is the time as faster the barrel will be filled	¨As more is the time as the volume of the water fill the barrel
G8	As more hours the tap is open, as more the tap will fill the barrel, while as less hours as less water quantity will be into the barrel.	¨as more time the water drops from the tap, as more volume of the water will fill the barrel.
G9	From the duration of time	As the time goes by, the volume of the water increases constantly.
G10	As much time we have, as more the barrel will be filled	The time is directly connected with the quantity of the water that will enter into the barrel.

Table 11: Comparative presentation of students expressions of proportionality, before and after working with MS

The 2nd column of the table 11, presents the answers of students at the end of the 2nd session with MS. Nine (9) of ten (10) answers express a relation of covariation between the two variables.

Students' expressions of covariance, and proportionality are already slightly evolved, towards more complete & scientific ones.

Related to the 'concepts' used by children is to be noted that:

(a) teacher has not introduced the term of 'proportionality' as such, consequently none child or group has mentionned it. The term of proportionality does not belong to the every day vocabulary of young students.

(b) The concept 'flow of tap' is not mentioned in an explicit way into the groups' answers, even if they have used it in the model that they had created (see previous paragraphs). This may be due to: (a) the fact that the factor was included into the question, (b) the difficulty of students to consider in an explicit way the conditions under which some relations are valid.

(c) The rich variation of expressions related to the time and the values of time, is characteristic of the fact , the time is not considered yet with each clear scientific status of a concept.

	Relation of proportionality (Pre)	**Relation of proportionality (Post)**
G1	+	+
G2	+	+
G3		+

G4	+	+
G5		+
G6		+
G7	+	+
G8	+	+
G9		+
G10	+	-
? otal	**6**	**9**

Table 12. Answers related to the expression of a relation of covariation among two factors/variables

Table 12, presents in a comparative way the codification of students answers: (a) at the middle of the first session working through MS, and (b) at the end of the second session.

4.2.8.CONCLUSIONS

(a) Young students can express themselves with the "semiquantitative relations"? Interaction with MS, could support them to a related learning evolution ?

Young students can express themselves through semiquantitative relations. But, finally it is to be taken into account that this issue, it is not the unique & central issue in order to work on modelling activities with MS.

The topics that students were involved to discuss and they were able to contribute to these discussions were the following:

- the factors that influence the phenomenon and the distinction among them [e.g. the variable of time, the variable of flow, the distinction between flow and volume of liquid, the distinction between the different values of a variable and its maximum value in a specific case].
- the regularities in a table of variable's values (the study of proportional relations between two variables, the distinction of the covariance of their values, the ability itself to 'read' a table of value).
- Generalisation of reasoning, from specific 'objects', to some at least slightly different objects, that could be implicated in a phenomenon: [e.g. the ability to recognize the similarity among the various recipients that MS library of entities include, and to consider that they can model the same phenomenon]

All students reach to create an appropriate model (e.g. at the end of the 2^{nd} session). Some groups of them have to be more supported and guided by the teacher than others.

- Students can express themselves, in terms of intuitive concepts: The most significant is that we were able to identify that students evolved over the sessions on: concepts construction (concepts that are implicated by each phenomenon under study), verbalization and distinction among them. This is a significant step over scientific concepts' construction & learning.

In almost all the groups, we can infer an evolution, on:

(d) problem analysis (clarifying the central question of the problem),

(e) intervening factors' identification,

(f) concepts use, concepts verbalisation ,

(d) expressions of proportionality among variables.

It is to be noticed that the students' progress over the modeling activities' sessions through the technology based learning environment has to be attributed to the combination of a number of factors: the ModellingSpace environment, the specific learning activities (and their design), the corresponding worksheets, the discussions among groups and the discussions among students' groups and teacher, and not only to the technology based learning environment itself.

(b) Young students have difficulties with concepts intervening during interaction with MS semiquantitative relations ?

All the students of the class had difficulties on the following:

(1.) To conclude about relations, when the simulation of entities is not produced or when simulation's behavior is not interpreted well. The incapacity to interpret the simulation's behavior leads to ad hoc uses of various variables (and/or entities), relations, and values of variables.

In some cases, children had to observe and regulate the algebraic values of each variable, in order to examine the compatibility among the values of variables, so as the expected simulation to be produced. It is not easy for so young students, to reason in a semiquantitative way (in terms of relations), and in the same time to have to think in a strong quantitative way, in order to make appear the simulation.

(2.) The difficulty to understand the meaning of the constant of a proportional relation among two variables, and its correspondence with the physical status of this constant: a third concept that must be linked with a specific manner (e.g. the flow of tap is the constant into the relation of the proportionality between time and volume of the water into the recipient. Students must link this variable to the relation of proportionality. This indication does not correspond to a natural way of thinking for children).

(3.) The distinction between Independent and dependent variable. The discussion on this distinction has to be continued with a number of examples during a range of different learning activities.

For some groups was easer to cope with these difficulties, while for some others was harder.

In all the cases, the most important and significant is: Read & study a number of different data representations (simulation, table of value, and bar-chart), try to reach specific inferences from each one, in order to conclude if a model is appropriate or not.

Possible confusions due to MS object-oriented entities:

We have to highlight the expressions of a few children related to the conceptualisation of their actions, such as *"in order to make our model, we used the above pictures."* *"We linked the pictures with the relation of proportionality'*.

The eventuality of mentioning the variables with the name of 'pictures', or 'objects' constitute a point that may cause new misconceptions to young students, in a long term. Thus it is to be taken into account by teachers, and guide discussions among students' groups, that could lead to a shared meaning and a socially accepted/ constructed naming.

(c) Young students meet difficulties with MS that could de-motivate them for their involvement to related learning activities?

Even if some students had important difficulties, in the beginning, they have not lost their interest and their motivation to continue work with MS. Almost all of them seem very motivated to continue the activities with MS.

The most significant is that students recognise that they have learned something specific, and they have the awareness on some of them (they are able to mention them).

(g) Is it possible to implement MS environment into a typical school without any tradition to ICTs use, and/or with a very low tradition to innovative projects, or with teachers applying traditional teaching approaches?

The present case study reveals to researchers that the implementation of MS learning environment, with the appropriate accompanying material (learning activities & students worksheets) can be fruitful for students. Even if teachers cannot assist on modelling process in an appropriate degree, they are able to find and assist on aspects that are appropriate and significant for young students .

5.3 Class of 14 years old students creating models involving semiquantitative relations and object-oriented entities.

[authors, researchers: George Tzortzakakis, Christos Mitsoullis, LTEE lab/Aegean)

5.3.1 Research Questions

a. Can students express themselves with the “semiquantitative relations”? Are students 14 years old able to identify the concepts that are involved into the phenomenon under study? What are the differences from 12 years old students working with a similar learning activity (see previous case study)?

b. What it seems that is the central learning support that MS offers related to the specific learning activity (according to teacher)?

5.3.2 Information related to schools and teachers

(a) Table of School presentation

School Names	Schools	Classroom	Number of pupils	Teachers’ name	Disciplines taught
3rd High School, Rhodes Town	*Lower level Secondary education School*	Classroom 1 : *B3* *(14 years old)*	20	Christos Mitsoullis	Teacher of Mathematics, Teacher-researcher in mathematics Education

(b) Information related to school

- *General information related to school identity.*

  The school is located to the Rhodes town. It dispose one PC laboratory, with 13 PCs (2 years old)& Internet connection.

- *Which is the teaching part of ICTs (duration, disciplines taught using informatic)?*

  During the typical program in 2003, there is a course related to ICT familiarization (one hour per week)

  This school can be considered, as a traditional one that has not experiences on integration of ICTs in every day courses.

- *Did the school already take part in research projects?*

  No.

(c) Information related to teacher

- *Which are the software usually used by the teacher?*

Noone educational software or any other kind of software for teaching/learning purposes

- *Did the professor participate already in research projects?*

Yes, one project related to mathematics education

- *Teacher profile:*

The teacher has an experience of 15 years in secondary school.

5.3.3 Learning Activity

- **Name of activity** : "Supplying a Container with wine " [See Annexe x] It is the same activity presented during the previous case study. The corresponding students worksheets are different & more elaborated ones.

- **Questions or assumptions related to the activity content and conception:**

  Assumptions: Appropriate activity for young student, given that give rises to a real phenomenon, that students could observe into the class (and not a phenomenon analysed only mentally). It contains three main parts:

  (d) a first part during which teacher and students work on a real experiment &

  (e) a second part during which students create and explore a model through MS.

  (f) the third and final part is dedicated to a global written report prepared by each group of students. Students refer on what they learned, on what were their difficulties, and they present the constructed model.

Activity Purpose: Activity that involve students to model through semiquantitative relations involving three variables.

- **Authors of the Activity:** The initial entities and scenario was conceived by Vassilis Komis, Assistant Professor (Univ. of Patras). The actual version of the scenario, associating the real experimental activity with the activity through MS, was introduced and prepared by George Tzortzakakis (Young Researcher, LTEE lab, Aegean University) while the students worksheets by the mathematics teacher Christos Mitsoullis, Rhodes, Greece.

<u>**Activity Description :**</u>

- ***Subject**:* Mathematics,
- ***Topic***: proportionality & graphs,
- ***Activity mode:*** Experimental situation, *& a model construction and model exploration mode*
- ***Activity central topic:*** Learning activity, inciting the study of "variables' and their covariation in a situation where, a container is filled with a liquid.

- ***Activity Approach considered:***

  (4) A problem is introduced and initially explored by a real-objects experimental situation. Then in order to be more extensively studied, students are introduced to the MS environment (in order to be able to do predictions),

  (5) Initial activity, situation were we have a problem and then we will introduce MS, because give us some additional possibilities (and not as a nice technological tool)

- **Choice of MS tools :** (a) Entities: object oriented entities (barel, chronometer),

  (b) Relations : semiquantitative ones of direct proportionality and inverse proportionality,

  (c) Models : object oriented models, with maximum three variables, and semiquantitative relations,

  (d) Graphs: Barcharts, and then graphs.

5.3.4 Context of Study

- **School :** Primary school, Ialysos, Rhodes. A primary school, in a village of Rhodes Island, where there is a low quality PC-lab, and only one teacher has a low experience with the use of ICTs. The teacher with the same classroom had already use PCs for activities with Word (6 sessions), for improving written expression purposes.
- **Classroom :** 14 years old students
- **Number of pupils** : 20 students
- **Duration of sequence** : 2 sessions (totally 2,5-3 hours)
- **Place (class, computer room):** Computer Room
- **Questions or assumptions compared to the context of the situation:** Normal Classroom of secondary school, with the whole class and the real teacher. So, implementation of the MS whole learning environment in real school conditions.
- **Role of the teacher**:

The teacher leads the activity and asks questions to the students, in order to verify understanding. The initial guidelines was that the teacher must avoid giving direct information to the students, related to implicated concepts & process, except information & guidelines related to MS interface.

- **Description of the context :**

  - Into the class exist: the PC of the Teacher as well as a Data Display (allowing the facilitate the demonstration of the MS main and basic features, as well as a model that is to be discussed by all the class, if needed)

  -A Video camera is located at the back part of the room.

Teaching Sessions:

Sessions	Duration	Aim	topic
1	1, 2 h (55 min)	Experimentatal situation Familiarisation with MS environment, using the 1st worksheet	Study of relations among variables that influence the phenomenon of a tap filling a recipient.
2	1 (45 min)	Continuation of the learning activity	

Table 1: Sessions Plan for 14 years old students, in Secondary School of Rhodes

1st Session: i) Start from a real experiment, think about factors and taking measurements

2nd Session: ii) Then, through MS create models involving Semi-Quantitative relations, Graphs & Tables

.

5.3.5 Population

- **Number of pupils** : 22
- **Age of pupils** : 14 years old
- **Organisation of Students' groups:** -20 student work in peers of 2 students. Group formation: mixed ability groups indicated by the teacher.

5.3.6 Data collection

- Material used to collect data
    - o Video –Camera: a camera covering the whole class, but focused on teacher.
    - o Logfiles of each group of students, interactions
    - o Models of students
    - o Printed Activity-worksheets of students
    - o Teachers written report after the end of learning activity sessions

- Type of data used for the results analysis*:* (a) answers on the students' printed worksheets, (b) teachers reports on the teaching process.

5.3.7 Results analysis

(I) Research question related to students conceptualization and reasoning modes

(a) Can students express themselves with the “semiquantitative relations”? Are students 14 years old able to identify the concepts that are involved into the phenomenon under study? What are the differences from 12 years old students working with a similar learning activity (see previous case study)?

The data analysed here-in-after, are extracted from students written worksheets.

Question1: Could you think on what factors play a role into this situation, and influence its evolution? How they are related among them?

Students groups	**Time**	**flow of tap (or just only tap)**	**total volume or shape of the recipient.**	**Volume of the water from the tap**
G1			+	+
G2		+	+	
G3	+	+	+	+
G4			+	+
G5			+	+
G6	+	+	+	
G7	(+)	+	+	
G8		+	+	
G9		+	+	
G10	+	(+)	+	
G11	+	+	+	

Table 1. Answers related to the factors that influence the situation: “a tap fill with a water a barrel.”

Terms used by students:

- ⇨ Volume of the water from the tap, litters of water
- ⇨ Flow of the tap, flow of water, flux, quantity of the water from the tap, the mean flow, force of water, velocity of water, etc. (it is to be noted that the different expressions in the Greek language form a wider range)
- ⇨ Volume of liquid into the barrel, the maximum volume of the barrel, the barrel of water, kilos of water, litter of water, the capacity of barrel, etc.

The range of terms that students use, in the place of concepts that they have taught about, is to be taken into account by the teachers in order to study and guide students' evolution.

Only four students over ten (4/10) take explicitly into account the time: Time is an abstract entity, (very familiar to everyone, but there is not an 'object' that apparently is involved to the visual situation.

<u>Question 2:</u> ***How they are related among them the factors that play a role into this situation, and influence its evolution*?**

Students' groups	**Student answers (question 2)**
G1	The barrel filling, depends on the flow of water, so, from how quickly water drops.
G2	It is depending from how quickly flows the tap water, as quickly it drops as faster the barrel will be filled.
G3	They are connected, because the one is depending from the other: as the flow will be less, as the time will be longer.
G4	The connection among the tap and the barrel is the water.
G5	They are connected with the following manner: The flow of the water and the time that is needed to fill the barrel.
G6	The flow of the tap during a specific period of time and the volume of the barrel. From these, they are depended the time that will be needed to fill the barrel and how much water will be contained to it.
G7	The magnitude that play a role in this situation, and influence its evolution are two: the mean flow of the water and the max volume of the barrel. In this way, as the volume of the barrel is bigger as will be increasing the mean flow of the water per second. Additionally, another magnitude is the time. In less time, the barrel will be filled less.
G8	The factors are: the capacity of the barrel and the flow of the tap. The water contribute to this situation, but it is not a 'magnitude'. They are connected, because the water of the tap will fill the barrel.
G9	More is the water, faster the barrel will be filled. The filling of the barrel is depending from the flow of the water, with the *force* and the *velocity* with which is running.
G10	The factors are: the volume of the barrel and the time during which the barrel will be filled. In according to the volume of the barrel and the flow of the tap, it will be needed a specific time so as the barrel to be filled.
G11	The factors are: (1) the flow of the tap per minute, (2) the capacity of the barrel, (3) the time that is needed so as to fill the barrel with water. The factors (1)& (3) is connected between them, according to the following way: As bigger is the flow of the water, as smaller is the time that is needed

	the barrel to be filled. The factors (2) and (3) is connected between them, according to the following way: As bigger is the capacity of the barrel, as bigger is the time that will be needed so as the barrel to be filled.

Table 2. Answers related to the factors that influence the volume of the liquid filling a recipient

After the first creation, of a related model students were invited to describe their model, into the worksheet.

Question 3: Describe your model (what entities and what variables have you used? Justify why you have used these relations

	"Students' written description of the models that they are created"
G1	The barrel, the tap and the timer. We clicked on the 'proportionality' because the variables are proportional
G2	We used the barrel, the tap and the timer. The 'magnitudes are the barrel with the timer proportional, because as faster the barrel will be filled, as less time will need. The tap remains constant.
G3	The objects are the barrel, the tap, the chronometer, and we have inserted the relation of proportionality.
G4	We selected a barrel for the volume, a tap for the flow of the water, and a timer for the time that it will be needed for the filling of the tap
G5	Objects: barrel, tap, timer // Variables: volume of liquid, flow, time (hour)
G6	Barrel (volume), tap (flow), timer (time)
G7	--
G8	--
G9	We selected Barrel, tap, timer
G10	Objects: barrel, tap, and timer. The magnitudes are proportional, because the volume of the water into the barrel is proportional to the time.
G11	The magnitudes that we have used are the tap, the timer and the barrel. The relation that we have used is the constant for the flow of the tap, and the proportionality for the volume of the barrel and the time.

Table 3. Students' written description of the created model.

Most of the students at this age, distinguish very well the object-oriented entities from the variables (G4, G5, G10). Other group of students are focused on the entities, and they use terms from the MS environment.

This fact may be justify given that students of the specific class have interacted with MS for just a short period of time (2hours), but it is a point where teachers must pay attention, so as to avoid the appropriation of students of some new vocabulary that does not facilitate the construction of scientific concepts.

Comparing to the answers on similar questions provided by younger students (see previous case study), we can infer that students at this age:

(a) Students 14 years old can easer reason with semiquantitative relations,

(b) they still present an object oriented view of 'magnitutes',

(c) most of them they do not indicate from the beginning the time as a magnitude.

(d) They use different terms (near or far to scientific ones) in order to indicate a taught concept.

It must be mentioned that teachers have not indicate hard difficulties of 14 years old students to reason with values of variables (in case that the simulation is not appropriate), as well as hard difficulties related to the distinction between an independent and a dependent variable.

(II) Teacher' Considerations

The next table presents teachers' notes and comments reported into the written teaching report, at then of the two teaching sessions.

"What really offers this environment is the possibility to analyse a phenomenon, to think about the factors involved in it, and to express them using various ways and relations.	***Main contribution of the MS environment***
"What is basically new in this software relates to modelling and the cognitive gains it brings. That is, the identification of factors and relationships while passing from entities to properties and from the latter to relations. If this can be done, it is enough to justify the usefulness of the software and thus the benefits of its introduction in schools.	***Teacher comments related to the MS specificities***
With the aid of this program, I was surprised to see that some concepts I considered as learnt, were not"	***MS activities for students' diagnosis***
"What I really observe as very significant changes in my everyday teaching routine were the following: For my everyday lesson to be successful what I feel is mainly needed is pupils to concentrate on the task and only secondly to think independently. I feel this even though I think it is wrong and despite the effort I put in my teaching. Usually the kids have no time and opportunity for dialogue either in pairs or in groups." "The 2 teaching sessions I had with the software were characterised by the tremendous increase in time devoted to independent thinking and by the fact that the pupils had the opportunity to exchange ideas amongst them. In the MS environment I did not have to worry about the pupils' attention and concentration on the task."	***Pedagogical approach, teacher strategies*** ***Students concentration*** ***Students motivation***

The translation into alternative forms of representation we -myself, as well as other teachers- were already used to do it and perhaps with a greater cognitive benefit for the pupil, because s/he was more actively involved, e.g. putting him/herself the values on the axes. Of course in the older years we gain time using the software. »	***Comment related to graphs in mathematics***

Table: Teachers considerations related to the two hours short MS activities implementation

5.3.8 Conclusions

(a) Can students express themselves with the "semiquantitative relations"? Are students 14 years old able to identify the concepts that are involved into the phenomenon under study? What are the differences from 12 years old students working with a similar learning activity (in comparison with the similar case study with 12 years old students)?

- Students can express themselves via the entities and the semi-quantitative relations.
- They have the same difficulties as the 12 years old students, but they can cope easier with them, and they need less time to progress through the learning activities sessions.
- Students of this age, they still present an object –oriented view of concepts, thus appropriate teaching strategies and learning activities are needed.
- Students are motivated and remain concentrated when working with MS learning activities

(b) What it seems that is the central learning support that MS offers related to the specific learning activity (according to teacher)?

Mathematics Teachers, consider that the most important aspect of MS activities related to modelling and the cognitive gains it brings: mostly on the identification of factors and relationships while passing from entities to properties and from the latter to relations, an aspect unique in MS. Thus, the possibility to analyse a phenomenon, to think in profound about the factors involved in it. This aspect is central and unique in MS. Other aspects, such as multiple representations, graphs, etc, could be studies also through other learning environments.

5.4 Primary School Students working with modeling activities in Chemistry: Exploring the potential of the Combination of real experiments & modeling, as well as the combination of qualitative with semi-quantitative modeling primitives

[Authors & researchers : Julia Fortouni, Nikos Kommatas, Fragkaki Maria, & Angelique Dimitracopoulou]

5.4.1 Case Study Research Objectives

This study is orientated in three main research axes:

(1) To investigate (a) if children can express themselves using modelling primitives of MS; (b) if children's familiarization with MS basic primitives is possible in a few sessions, and (c) what difficulties spring forth during their interaction with ModellingSpace environment.

(2.) To identify the intuitive notions as well as the misconceptions of students that are emerged during the corresponding learning activities (related to chemistry), as well as to investigate how they are emerged and how they are evolved during the interaction of young students with ModellingSpace environment and related activities.

(3.) To explore the significance of qualitative models (concept maps) in relation with simple semiquantitative relations' based models. To investigate the importance of concept map cognitive tool and its role in the learning/teaching process

5.4.2 School, teacher & researchers involved

The case study concerns the implementation of specially designed learning activities , that were implemented to the 7th Primary School of Haidari, Greece. It is a public school, that dispose a PC lab, installed four years ago.

The teacher (Mr. Nikos Kommatas**)** is the teacher of the 6th grade class of students: a primary school teacher that is not specialist to chemistry education, but it is recently interesting to research action practice (he was student of post graduate studies).

The intervention and the questions of the teacher, according to him "aim at the provocation and cooperation of the students, the revocation of precedent knowledge, the expression of feelings and thoughts, the description and the understanding of information, etc."

Two researchers participated in the research mainly as observers, intervening only when necessary for eventual technical problems as well as for data collection (video camera) , avoiding as much as possible to influence students' actions, during the teaching session.

5.4.3 Students' characteristics

There were 6 children, volunteers, participating in the case study (4 girls, 2 boys), from the 6th grade of the 7th Primary School of Haidari.

According to the needs of our study they were separated in three groups of two members each. The basic criteria for the *formation of the groups* was students' technological background, in order to be sure that each group can cope with the technological demands of the activities. However we also took into consideration the children's preferences (class sociogram). The group remained the same from the beginning until the end of the procedure. For reasons of discretion, pseudonyms were used instead of the students' real names, where the students are mentioned in this paper.

The school performance of the students ranged from excellent to very good. During the school year (approximately 4 months ago), the students had already been taught the relative chapter "Compounds – Solutions" from the 6th grade school textbook "Search and discover". The notions they had already worked on were: compound, solution, heterogenous – homogenous compound, saturated solution.

All the students were more or less familiarized with the use of computers; four of them had a computer at home. They had never used exploratory educational software. They had only scarcely used other applications such as word processing, multimedia encyclopedia and the Internet, while they were more familiar with video games. However all of them stated that they were very interested in the use of the computer.

5.4.4 Context and specific conditions of teaching sessions

The students came for the first time in contact with ModellingSpace a week before holding this study. There was a meeting with the students, in order to inform them about the research procedure and demonstrate the environment ModellingSpace. In the beginning there was a demonstration of the software by the researchers, which lasted approximately 10 minutes and afterwards the students were free to explore the software environment.

In the same meeting and with the help of the students, there was setting up of the area and the materials to be used. We did not use the small school laboratory, because of confined space, or the old school computers: during the initial demonstration, we ran into difficulties running the program. We decided to use two portable computers and one desktop computer which were installed to the normal school classroom. Into the same classroom the material for the real objects chemistry experiments, were installed (see figure 1).

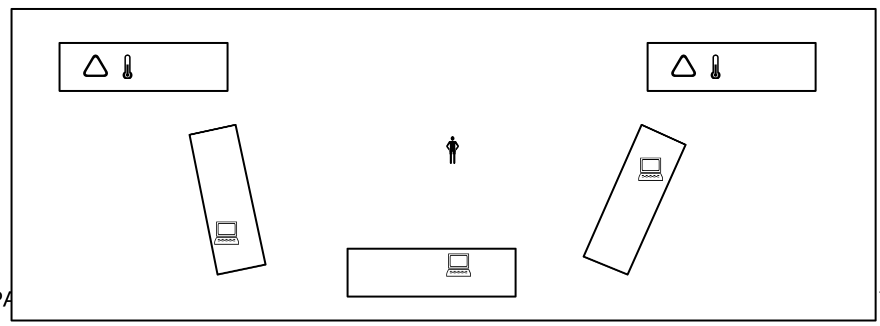


Figure 1: The plan of the class

The research study consisted of seven teaching sessions (Table 1).

Sessions	**Unities**	**Teaching Goals**	**Duration**
Preliminary session	Demonstration of the software "Model Creator"	*Familiarization with the software environment. *Understanding of the basic tools and functions.	45 minutes
1st session	"Preparing sugar water"	*Distinction of the basic meanings of solutions. *Qualitative analysis and expression with concept maps	45 minutes
2nd session	"One Basic solution property"	*Understanding "homogeneity" as a basic solution property. *Processing the modeling of homogeneity	45 minutes
3d session	"The meaning of content"	*Understanding the meaning of content. *Processing the modeling of content.	45 minutes
4th session	" Diluting sugar water"	*Understanding the process of diluting solutions. *Processing the modeling of diluting.	45 minutes
5th session	" Condensing sugar water"	*Understanding the process of condensing solutions. *Processing the modeling of condensing.	45 minutes
6th session	"Contemplating the basic meanings, properties and processes of solutions"	*Understanding the basic meanings, properties and processes of solutions. *Qualitative analysis and expression with concept maps.	45 minutes

Table 1: Table of sessions and teaching goals.

5.4.5 Learning Activities planning

The planning of the teaching interventions was based on the organization of educational learning environments, in order to get the students to actively participate in the learning process (research, collect, record, analyze information), implement their knowledge for the realization of authentic activities for the solution of problems, cooperate and interact with their classmates as well as interact and follow the lead of the teacher.

The thematic unity which was chosen was "Solutions" of the course "Research and discover" of the 6th grade of Primary School and is based on six allocated Worksheets .which have the following characteristics:

- The students are involved primarily in experimental procedures in the school laboratory (usage level)
- They express these experimental procedures with meanings found in the concept maps in the MS environment (symbolical level)
- Using model activities (virtual level), in the MS the students gradually:

  a) May understand a basic solution property: homogeneity, via specific visualization that is supported by corresponding entities of MS.

  b) Study the basic procedures of solutions: diluting, condensing

  c) May Construct the basic concepts, procedures related to solutions, via the construction of concept maps.

The work sheets, accompanying every single thematic unity, were created initially by Christos Passalis, chemistry teacher, for the teaching of the corresponding thematic unity of the 2nd High School class and were modified by the researchers. In particular, the language was simplified, difficult meanings and activities were removed, and supporting activities were added according to the educational planning needs.

The learning activity (SOLUTION) with the corresponding worksheets is presented to the Deliverable D5. Figure 2, presents as an example the planning of the second worksheet.

ACTIVITY 2: REALIZATION PLANNING

TITLE: "Solutions: A basic property of sugarwater and solutions"

AIM:

The basic aims of the activity are:

- ✓ Make the students understand a basic solution property (homogeneity)
- ✓ Involve the students in the process of modeling the homogeneity of solutions
- ✓ Correlating the modeling process using the experimental procedure used.

MATERIAL-MEANS-TEACHING PERIOD

Laboratory water (de-ionized), sugar, spoons, straws, boiling containers of 100ml and three computers downloaded with the "Model creator" software. The required time of the activity is 30min.

INTRODUCTION

Initially the children, through their activity, experimenting with simple material and with the appropriate step by step guidance from their teacher, they come in contact with the homogeneity property of solutions. Afterwards, using the "Model Creator", they explore the virtual model of sugarwater and correlate it with the actual experiment.

PROCEDURE

1. The children are divided into groups of two and move in the area specially formed for the experiments. They are given work sheet 2 and experiment material.

2. Each group tries to execute the instructions of the work sheet for the preparation of sugarwater. The children are called to taste from different places of the solution and compare the sweetness of the taste.
3. Each group presents the procedure followed and the results of the comparison. There follows a discussion and management of problems and conflicts presented, with the teacher's participation. With the appropriate step by step guidance the groups end up in a joint comparison conclusion (there is no difference in taste) and efforts are made to further explain the results of this comparison.
4. The children fill out the work sheets (intergroup communication) and are called to depict microscopically the result of the comparison, drawing on paper the sugar molecules as small circles, while the water molecules are not depicted but the water level is marked with a line. There is a presentation of the drawings to the other groups.
5. The children are transferred to the computers and to the MC environment, following always the instructions of the work sheet, creating and exploring the model of sugarwater. There is a discussion with the participation of the teacher regarding the differences when compared with the model they drew on paper.
6. There is a presentation, comparison and explanation of the model from each group (intergroup communication). The teacher sets the students thinking about the distribution of the circles that depict the molecules of diluted sugar in the volume of the solution, while there is a correlation with the experimental data. The children while describing the distribution mention that "the sugar is evenly distributed" or "the sugar is separated equally in different places in the water".
7. The teacher elicits that the same thing happens in every solution and this is a basic solution property called **homogeneity**.

Figure 2: *Realization planning of the modeling activity, according to the 2nd worksheet*

5.4.6 Data sources

The data source of the research were: (a) the notes of the aforementioned researchers, (b) the videotaped records, (c) the interviews (by sound tape recorders), (d) the completed work sheets, as well as (e) the models stored by the students.

The whole procedure was videotaped focusing basically on one group, but also inter-group presentations and communications, so as to record the general cooperation and behaviour of the students. We used additional tape recorders for the recording of each group's talks. After the end of the teaching sessions the students were asked for their opinion (interviews), about the procedure and were recorded.

5.4.7 Presentation, analysis and interpretation of research results

The basic findings of the research group following the observation of the teaching sessions, based mainly on the videotaped recordings, the direct observation of the children and also the final results of their work (stored models, filled out work sheets), concerns three thematic directions:

With reference to the means of expression and the tools available to the program.

5.4.7.1 The means of expression and the tools available

During the demonstration of the MS software to the children, we observed the quick familiarization with the standard functions of the MS (entities, properties, relations). In particular, only 45 minutes were needed for the learning of the basic potential of the software. Additionally, while analyzing the video it was obvious that the use of the interface and the positioning of the objects (entities) and relations (figures 4 and 5) are easily and quickly performed.

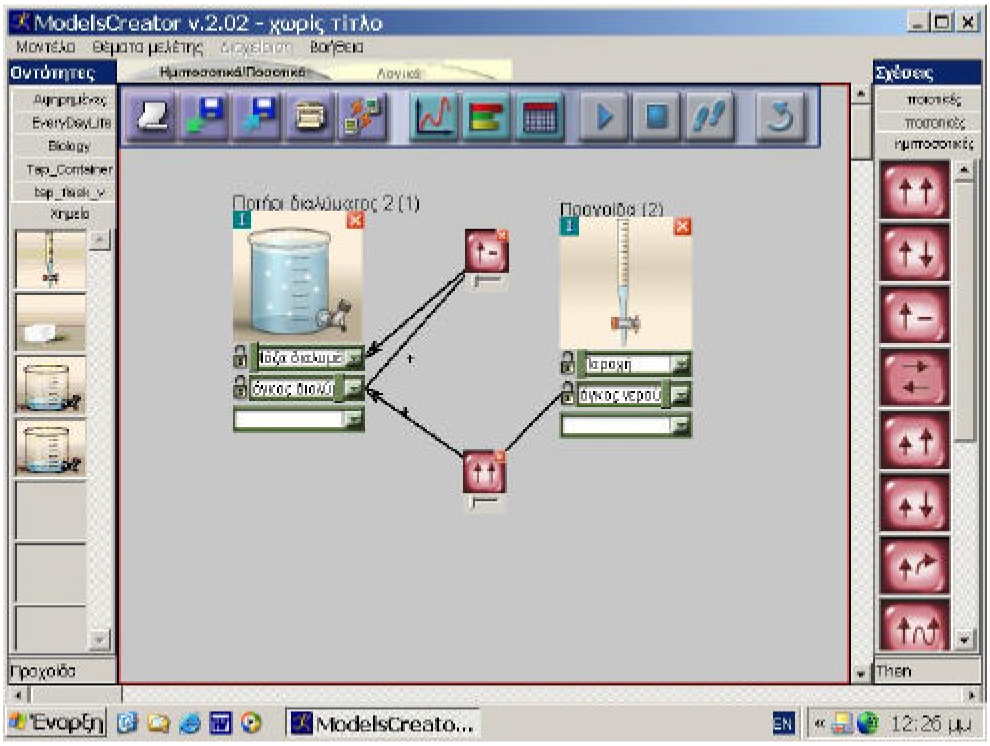


Figure 4: Semi-quantitative model of the 1st group (4th session), in the MC environment.

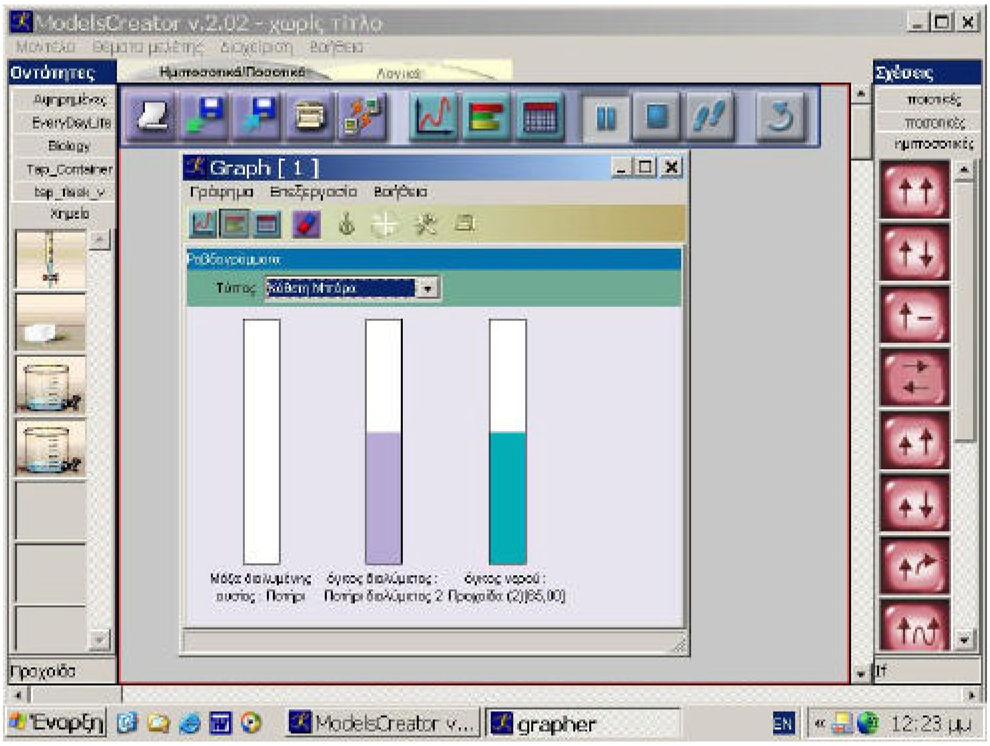


Figure 5: The equivalent triple bar chart of the model

During all the sessions, none of the children expressed any inconvenience to the perspective of working with this particular environemnt; on the contrary most of them expressed vivid enthusiasm and satisfaction every time they successfully created their model. Here follow some characteristic sound extracts (1 and 2) from the children's interviews:

Sound extract 1.

<u>Anastasia:</u> *It was very nice and I would like it if there were more such programmes.*

Sound extract 2.

<u>Aris:</u> *I didn't like it when Mr. Nikos told us that this will be the last session where we will work together for this programme.*

During their occupation with the activities, all the children showed particular convenience in using the work environment, while the cooperation between them was specifically advanced. In particular we report incident 14 as a characteristic example of in-group cooperation and incident 15 specific of intergroup communication (figure 6). Additionally we quote from sound extract (3) and from the children's interviews:

Figure 6: Photo-instant of intergroup model presentation

Sound extract 3.

Mary: I quite liked working in groups and manufacturing models and made experiments.

Our basic findings concerning the children's ability to express themselves through the MS tools, are that the tools provided by the MS environment, are not enough on their own, to guide the children to express their cognitive schemes. Instructive intervention is catalytic in its role, in order to set the safe boundaries of a model and not lead the children into arbitrary conclusions. There was also a need quite often, possibly due to the children's young age, to correlate the models to the experimental data in order for them to comprehend and clarify difficult meanings, so as to be able to express them through their models. (Incident 21 and sound extract 4)

Incident 21 (4^{th} session) the teacher resorts to correlation with the experiment in order to guide the children modify their model.

6:45 p.m.

Teacher: Children, let's stick to our first activity. Let's connect the solution volume to the mass of the diluted substance. Let's find a connection. I can see that you all put a ratio analogy. Let's connect that with the experiment. What did we increase there?

Mary: The solution volume

Teacher: What was the mass of the diluted substance?

Mary: It was stable

Teacher: So what is the ratio?

Aris: I get it

Mary: So do I

Sound extract 4.

Mary: The representation of the model in the computer is not enough. I think we also need the experiment. It was much easier to understand the model in the computer, when preceded by the experiment.

Some difficulties which were traced are of secondary importance and concern mainly the characteristic attribute of the environment in giving possibilities of expression and visualization in many levels (cognitive and age-related), resulting sometimes in difficulties and confusion for the “young” users. The teacher’s intervention is catalytic in providing solutions, explaining to the children what a burette is (sound extract 5), or describing the ratio analogy (when one gets bigger the other one gets also bigger) and reverse ratio analogy (when one gets bigger, the other one gets smaller).

Sound extract 5.

Anastasia: *It was a lot of fun trying to find a word like burette.*

It was also suggested to the children to use bar charts for the visualization of the relations, instead of graphic charts when these were too complicated. Another difficulty which was expressed by the children (sound extracts 6 and 7) was the sudden “loss” of models in two groups (three times in one group). We cannot say with certainty whether this was a result of a software flaw or some erroneous handling by the children. Nevertheless we established some technological weaknesses of the programme.

Sound extract 6.

Kostas: *I did not like loosing the last concept maps three times.*

Sound extract 7.

Anastasia: *I did not like loosing the last model because it was very nice!*

We can therefore conclude that the use of the basic tools of the software (entities, relations, properties) is quite easy for the students. Quite a few times the students, to the researchers’ surprise, went on to aesthetic interventions on their own initiative (incident 20).

Incident 20 (6th session)

8:07 p.m.

Aris: Sir, sir!

Teacher: Wow! What have you done there?

Aris: We coloured it, we changed the background

Teacher: That’s good! Now try a lighter colour so the model is better represented

Aris: Yellow? Light blue?

Teacher: Light blue.

The open exploratory environment of MS satisfactorily responds to the children’s particular learning demands. It offers tools that effectively intervene in their thought process, as they become the motive for negotiating meanings, advancing at the same time not only the communication between them and their cooperation, but their interaction with the teacher. The importance of communication and dialogue between students and teacher and among the students is especially stressed in the bibliography, as it constitutes a critical factor for the active exploration of educational technology based environments (Lim, 2001).

5.4.8 Children's conceptualizations (intuitive concepts, misconceptions & concepts evolution)

Taking into consideration the bibliography and our teaching experience we conclude that Primary School students have alternative perceptions concerning solutions and all the relative meanings, while they find the understanding of their properties difficult.

a) Misconception of the meaning "dilution of a substance"

While analyzing the video we observed that two children from different groups (Aris and Mary), while preparing the sugarwater, used the phrase "the sugar disappeared" to describe the dilution of the sugar in the water (incident 1 and incident 2)

Incident 1 (1st session)

6:25 p.m.

Teacher: What are you doing?

Aris: Making sugarwater

6:26 p.m.

Teacher: The first group. Aris, what happened? Tell us!

Aris: <u>I made it disappear!</u>

Teacher: What did actually happen? Tell us what did you originally put in there

Aris: Water, sugar and I mixed it

Teacher: Where is the sugar? <u>I cannot see it…</u>

Aris: I made it disappear

Teacher: It disappeared? What did actually happen? How did it disappear?

6:27 p.m.

Aris: I mixed it, it blended with the water and was <u>diluted</u>

Teacher: The sugar is obviously somewhere inside the water when we say that it disappeared.

Aris: Well, yes in a way…

Incident 2 (1st session)

Teacher: I want you to hold the two mixtures in your hands and tell me what kind of differences you see. Well, tell me Mary.

Mary: Well, in the first bottle where we put the rice, the rice has settled at the bottom and the water is turbid, while in the second glass that has saltwater inside, the salt has disappeared, it has dissolved and the water is clear.

The misconception seems to be changed in the process during the experimental procedure (incident 3), but also during the creation of the qualitative model with the MS, where the children "map" the experiment and make the meaning of the solution and the relative meanings clear: dissolvent, diluted substance, heterogeneous-homogeneous compound (incident 4 and 5).

Incident 3 (1st session)

6:38 p.m.

Teacher: Aris, what is this solution made of?

Aris: It is made of water and sugar

Teacher: Which is a simple way to prove that there is sugar and salt in the sugarwater and in the saltwater respectively?

Aris: By tasting it (The same answer was also given in the 1st work sheet)

Incident 4 (1st session)

Group 1 (Aris-Anastasia) explaining their model

7:02 p.m.

Aris: We wrote the word solution on a little window and we analyzed the saltwater which consists of salt and water and the sugarwater which consists of sugar and water

***Incident 5** (1st session)*

Group 2 (Mary-Eleni) explaining their model

7:05 p.m.

Mary: We have made a relation where we say homogeneous compound or else solution and then we explain that the solution consists of water, salt or sugar in two different little dialogue bubbles.

b) Misconception related to the notion of "homogeneity"

Another misunderstanding shown through our research data, concerns the property of homogeneity of solutions. In particular Aris (group1) and Kostas (group 3) while in the experimental procedure (when asked to compare the sweet taste at two different levels), thought that in the sugarwater solution, there was more sugar at the bottom than at the surface (incidents 6 and 7).

Incident 6 (2nd session)

Group 1 (Aris-Anastasia)

7:26 p.m.

Teacher: Aris drink some from the top, some from the bottom and tell us what you understand. What difference does it make when you sip the sugarwater from the bottom and when you sip it from the surface?

Aris: When I sip from the bottom there is more sugar.

Teacher: Could you tell the difference?

Aris: Yes, I could

Incident 7 (2nd session)

Group 3 (Mary-Kostas)

7:28 p.m.

Teacher: You Kostas, what do you say? Is there a difference?

Kostas: Sir, no there is no difference.

Teacher: Why?

Kostas: Because if I say that there is you will make me drink…

(Everyone laughs…)

Teacher: I want you to explain it to me.

Kostas: I believe that there is a difference, because, down at the bottom, sir, there is more sugar, because that's where the most of the sugar will go

According to the researchers observations Aris' misunderstanding is a result of a "laboratory error" (the sugar may not be properly diluted), while Kostas' is due to mistaken intuitive perception, that sugar, because of its weight settles at the bottom.

The modeling possibilities of the experimental layout that the entities of MS dispose, in order to achieve a versatile approach of the phenomenon and mainly its visualization possibilities (sugar molecules depicted as small circles, equally distributed in the water), can support students to overcome the misconceptions and the confusion of the experimental procedure and "clear out" the meaning of homogeneity (incidents 8 and 9). Thus in work sheet 2, they represent the distribution of the sugar molecules in the water correctly (Figure 7).

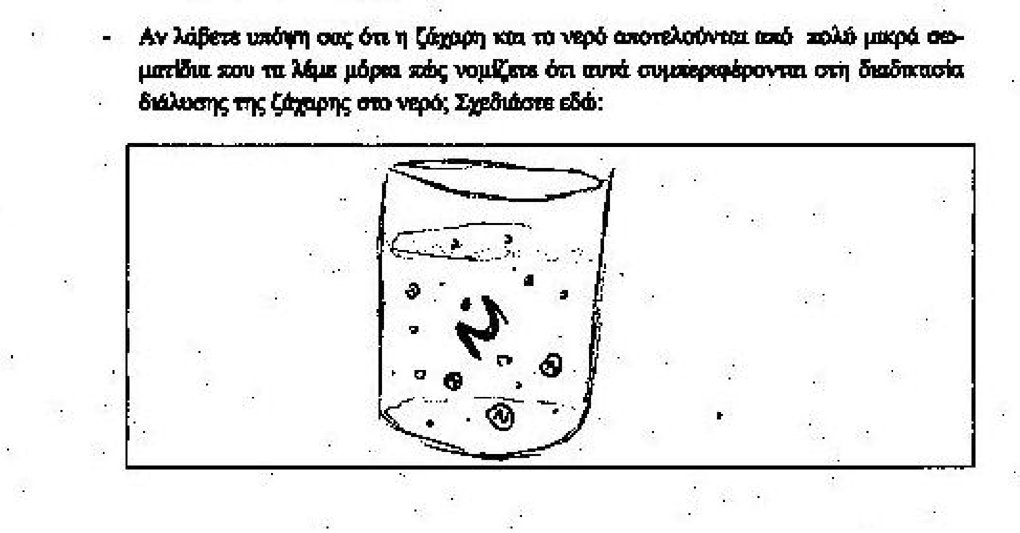


Figure 7: Activity from 3rd group's work sheet 2

Incident 8 (2nd session)

Making of semi qualitative model by Group 3 (Mary-Kostas)

7:44 p.m.

Teacher: How is the sugar separated?

Kostas: In many places

Teacher: You mean the distribution is equal?

Kostas: It is divided

Incident 9 (2nd session)

The groups gather to discuss on the models they have made and the conclusions they have ended up with

7:78 p.m.

Teacher: We are interested in how the sugar is distributed within the solution. What did you observe?

Kostas: I am not sure…How does it enter the same, I mean, in the water. The sugar is divided the same into different places?

c) <u>Construction of the concept "Solution Content"</u>

According to the basic principles of constructivism, the students' previously existing knowledge plays an important part in the learning of new meanings (Ausubel, 1960), since it is on them that the building of knowledge is based. Thus the detection of previous knowledge and experience, gives the educator the possibility, on one hand to diagnose potential misconceptions and with the appropriate didactic strategies to manage the cognitive conflicts, on the other hand he can bridge the gap between formal and non-formal knowledge, completing and readjusting the children's cognitive models. New meanings are embodied in the existing cognitive structures and thus "learning acquires meaning" (meaningful learning), (Novac, 1991). This step by step guidance consists "scaffolding", which the teacher provides, in order for the students to advance in to the zone of proximal development (Vygotsky, 1986).

The construction of the concept of 'solution content' provoked our investigative interest due to its particular difficulty on one hand and on the other due to the clear distinction of the stages which the children followed, in order to conquer it and embody it to their previously existing cognitive structures. Thus, according, to our research data, we distinguish the following stages:

1) *__The importance of previous knowledge:__* Analyzing the video, the importance of the children's previous knowledge is proven, in order to comprehend the new meaning. Thus we observe, that the two children from group 3 (Kostas-Mary), present and explain the experimental data, not only based on observation and the senses (taste), but also based on their existing knowledge (they have already conquered the meaning of homogeneity in the previous session). Mary, in particular (incident 10), is based exclusively on her previous knowledge that sugar is equally diluted in the same way, while in Kostas (incident 11), there is a cognitive conflict taking place, since the experimental data do not verify his previous knowledge.

Incident 10 (3rd session)

(Each group empties slowly the glass containing the sugarwater they made during the previous session and at the same time they taste its sweet taste, while its volume diminishes)

Group 3 (Mary–Kostas)

7:59 p.m.

> *Mary: Since we said that sugar is equally diluted in all of the solution, the previous cannot have been sweeter and this which is less to be less sweet…*

Incident 11 (3rd session)

7:58 p.m.

> *Teacher: Tell us what you think. In the beginning you tried some sugarwater that had a larger quantity of solution, sugarwater. You tried it. It had a certain sweet taste. Now you try this one that is left which is less sugarwater. The taste remains the same, or is it different to the previous one?*
>
> *Kostas: Sir, look…I believe…I know which one is correct but…*
>
> *Teacher: What did you understand? Tell me!*
>
> *Kostas: __**I understood** that this was not as sweet as the previous one, **but sir I know** that it is correct to be the same.__*
>
> *Teacher: Why should it be the same?*
>
> *Kostas: Since I put the same spoonful in, this is how much it contains.*

2) bridging the gap between formal and non-formal knowledge: The educator with the appropriate didactic manipulation and plenty of guidance due to the difficulty of comprehending this particular meaning), introduces the children to the term "content" and helps them connect this new meaning to the already known meaning of homogeneity (incident 12).

Incident 12 (3rd session)

8:04 p.m.

Teacher: Apart from the word homogeneity, is there another word which has to do with the homogeneity of solutions. It refers to the quantity of the diluted substance.

Children: _ _ _

Teacher: The substance is contained. How would we say it?

Children: _ _ _

Teacher: The content of the solution. When we say content, then, what do we mean?

Mary: The space… the mass of the diluted substance…

Teacher: The mass of the diluted substance which is found in the solution, Content.

3) *comprehension and embodiment of the new meaning:* According to the researchers' estimations the experimental procedure and the educator's interventions, did not lead the students in comprehending the new meaning. As it is obvious in the previous incident (12), the children cannot adequately respond to the dialogue that the educator provokes, there is silence and only Mary seems to "suspect" the sense of the meaning. Thus the use of an intervening tool, which the students can use in order to assimilate knowledge (Crawford, 1996), is deemed necessary. The children, building the model, in the MS environment, understand the preceding experimental procedure better, and construct more scientifically the meaning of "content". In search of an "even better model", the environment support the children in a way that can show them their inconsistencies and end up in a scientifically proven proposition (incident 13). Thus new meanings (figure 8), are embodied in the old and the children express themselves with "scientific speech" (incident 18 and sound extract 5).

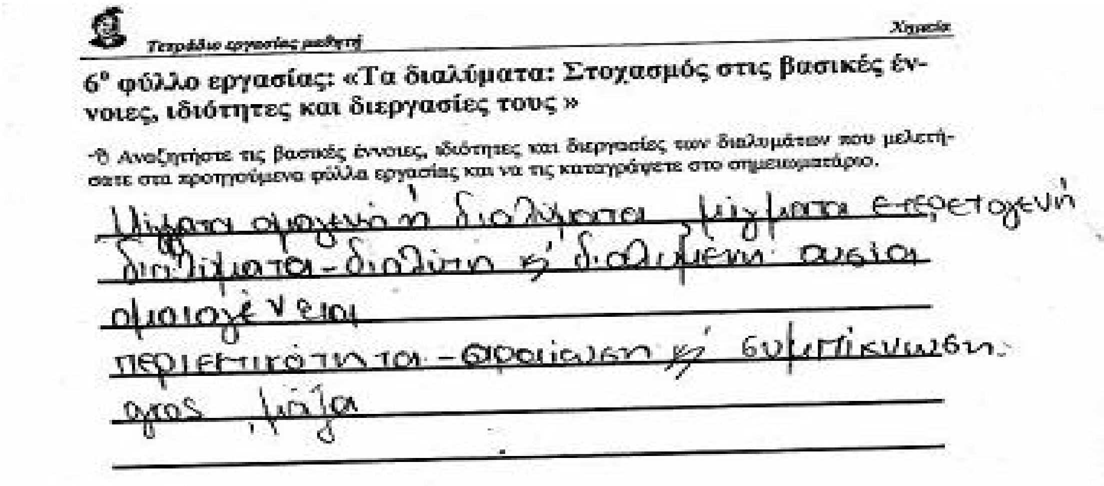


Figure 8: "New meanings", as shown on work sheet 6 of the 3rd group. [translation:

Sound extract 5.

Mary: I quite liked using more complex words in the concept maps and this is important in enriching our own vocabulary.

Incident 13 (3rd session)

8:23 p.m.

Teacher: Good! Kostas, why don't you run it one more time so we can see?

Mary: When the volume decreases so the mass decreases.

Teacher: What remains constant?

Kostas: The water quantity and the sugar.

Teacher: Which is the content? Run it once more. As the volume grows so the mass grows. They are proportional.

Incident 18 (6th session)

Mary analyzes her group's meaning chart to group 3.

Mary: We have started with the word compound; we connect two small dialogue bubbles which show the connection between homogeneous and heterogeneous, which is the main property of the solution. Afterwards we extend the word homogeneous which we connect to the solution.

Teacher: A homogeneous compound is a solution, very good!

Mary: The solution is consisted of water and in the other small dialogue bubble of salt or sugar. We have put an extension to water which says dissolvent. And we have put an extension to salt or sugar which says diluted substance. On the solution (laughing with all the extensions…), we put another extension with the basic property which is the word content which has two more extensions with the words dilution and concentration.

Furthermore, with the available tools, the variable of content is visualized with a bar chart and a graphic chart (figure 9).

Figure 9: Visualization of the model with bar chart in the MC environment

We can therefore conclude that the use of the MS tools strengthens the students, in order for them to develop their own skills in the reconstruction of initial conceptions and the construction of new meanings, without having to rely entirely on the teacher. The possibilities of the environment provide the students with opportunities to experiment, creating a motive for learning and implicating them in a procedure, where knowledge is viewed as a mental construction and not a memorizing procedure.

5.4.8.1 The importance of concept maps (qualitative models) and the role of the concept map cognitive tool in the learning process

The technique of concept mapping was developed by Professor Joseph D. Novak, at Cornell University. It was based on David Ausubel's theories (1968), who emphasized on the existence of previous knowledge in order to learn new meanings. Novak (1991) ended up in the conclusion that "learning with essence includes the assimilation of new meanings and their embodiment in the existing cognitive structures".

Concept mapping is a dynamic cognitive tool, which supports the educational procedure advancing new learning goals, such as high level cognitive abilities (problem solving, cooperative work in complex projects and post cognitive abilities that allow the control of the learning procedure by the students themselves (Dimitrakopoulou, 2001).

In this study, the children's expression through concept maps (qualitative models for the MS environment), occurred in the first and last (6^{th}) session. In the first session, in particular, each group made two concept maps, an initial and a final one. The final maps were formed after the intergroup presentation of the initial maps in class. Similar maps (initial and final), were made in the last (6^{th}) session. There were 12 maps made in total, 6 initial and 6 final.

The concept maps were analyzed using quantitative criteria (the number of junctions and relations, the depth of the connections), as well as qualitative ones (their shape and contents).

The total (sum) of the junctions and their relations in the initial and final maps (1st and 6th) session are presented in figure 10. The increase of junctions and relations in the final maps is obvious and is proof of the embodiment of new meanings to the children's cognitive structures.

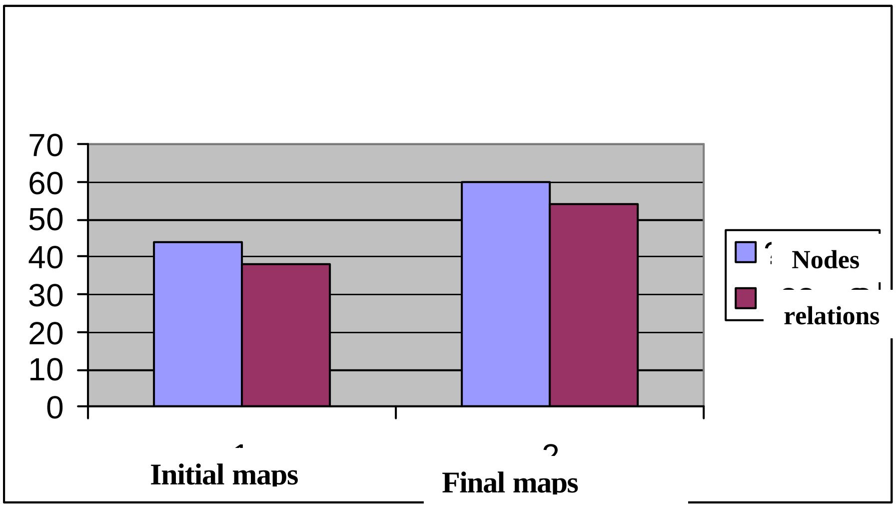


Figure 10: Comparison chart: initial-final maps.

Quantitative differences in the sum of junctions and relations

An even more analytical presentation of the facts (figures 11 and 12) shows the difference in the junctions and relations per group. In five out of the six final maps there is an increase of junctions and relations, while in one they remain the same. We have to note out the greatest difference (3rd group in first session), where the original junctions and conjunctions were 6 and 3 respectively, while the final, 12 and 11 respectively. (Figures 13 and 14).

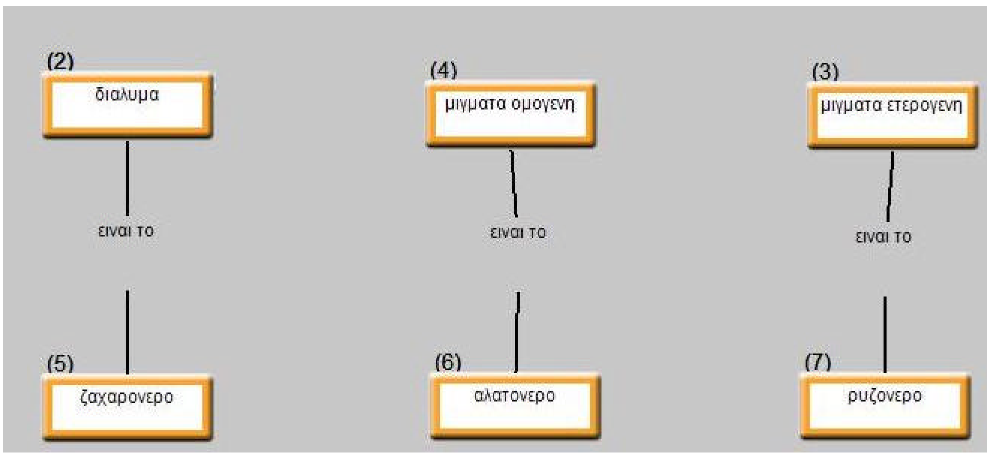


Figure 13: Initial map from group 3 (1st session)

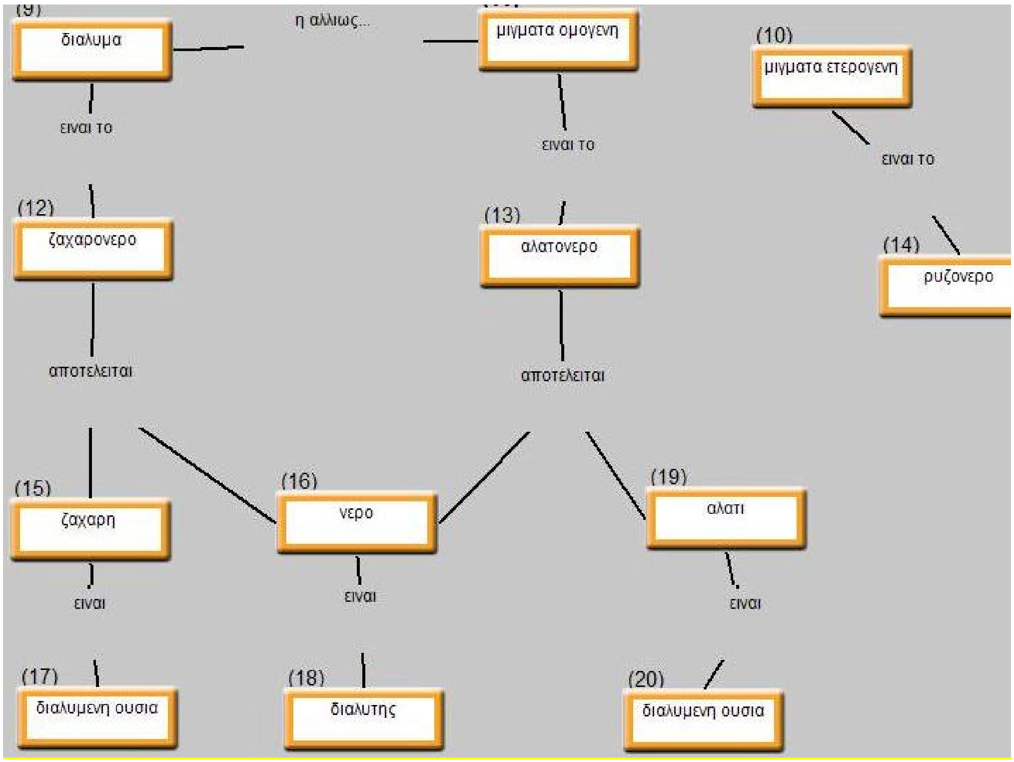


Figure 14: Final map from group 3 (1st session)

The depth of the connections shows an important increase in the final maps, a fact that is proof of better organization and hierarchy of the meanings. Another common feature of the connections in all the maps is the fact that all relations are determined by verbal labels, a fact attributed to the children's familiarization with the technique of meaning mapping.

As far as the map structure is concerned (figures 11 and 12), three of them didn't change shape while three were improved and evolved in a more complex form. Thus, from the initial three maps having the simple "star" form, there remains only one final, there are two final maps in the intermediary category of the "tree" (as an evolution of the previous "stars"), while using the more complex "grid" category, there is an increase in the initial ones from two to three. Only one map (initial) had indefinable structure (figure 13), while there was absolutely no linear form, a fact that caused the researchers' initial surprise, since it is mentioned in the bibliography as the predominant form of concept mapping in Primary School children, (Karasavvidis, 2002) and (Mavrantonaki, 2001). This was attributed though, to the particular activity and familiarization of this class, during the last school year, with the technique of concept mapping.

INITIAL MAPS 1ST SESSION					FINAL MAPS 1ST SESSION				
Team	**Junctions**	**Relations**	**Depth**	**Shape**	**Team**	**Junctions**	**Relations**	**Depth**	**Shape**
1	7	6	3	Star	1	10	9	4	Tree
2	4	3	2	Star	2	6	5	3	Star
3	6	3	2	Indefinable	3	12	11	4	Grid

Figure 11: Comparative tables initial-final maps 1st session

INITIAL MAPS 6ST SESSION					FINAL MAPS 6ST SESSION				
Team	**Junctions**	**Relations**	**Depth**	**Shape**	**Team**	**Junctions**	**Relations**	**Depth**	**Shape**
1	6	7	3	Star	1	9	8	3	Tree
2	10	8	3	Grid	2	10	8	3	Grid
3	11	11	5	grid	3	13	13	5	Grid

Figure 12: Comparative tables initial-final maps 6th session

Analyzing the facts in each session separately (figures 15 and 16) we end up in the following conclusions:

- In the first session we have an impressive increase of nodes, relations and depth of connections (figure 15).

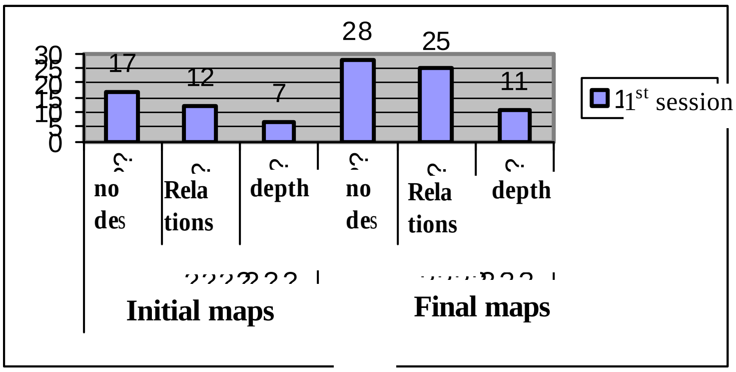


Figure 15: Bar chart of the comparison between initial-final maps of 1st session

- In the sixth session we observe a relative increase of junctions and relations, while the depth of connections remains stable (figure 16).

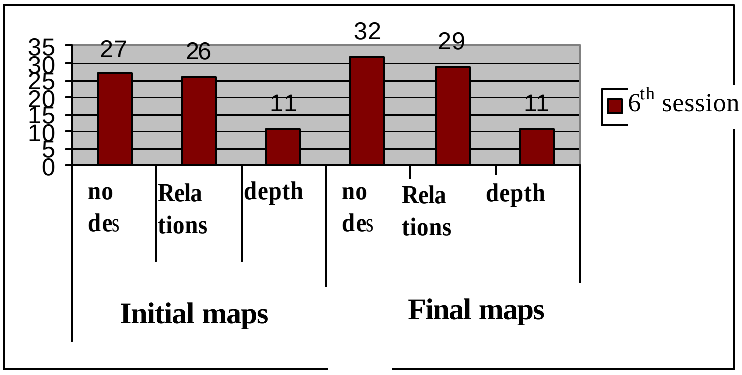


Figure 16: Bar chart of the comparison between initial-final maps of 6th session

A concept maps which is made by a group of children represents the group's ideas (incident 14). In this case the concept maps constitutes a communicational tool between the group's members, who have to express and negotiate their ideas and reach an agreement on a common meanings structure and their connections between them on the map (in-group communication). However, (as seen in incident 15), the concept mapping are tolls for negotiating meaning (Novak & Gowin, 1997) also between the groups (intergroup communication). Thus the interaction between the group members is enhanced and group cooperative learning is strengthened (Matsagouras, 2000).

Incident 14: (1st session)

(sound extract from group 3 during the making of the final meanings chart)

Mary: Compound… another cloud…

Kosta: Sir, may I ask something?

Teacher: Yes

Kostas: Do we have to write compound, dash, solution?

Teacher: I don't know

Mary: Neither do we!

Teacher: Think about it, talk about it amongst yourselves

Mary: We will describe the components of each solution and we will use a basic relation between solutions and compounds.

Kostas: Something like that…

Mary: Yes, well what do we write in solutions… which ingredients?

Kostas: Let's put sugarwater

Mary: Sugarwater, saltwater…

Kostas: Let's analyze sugarwater

Mary: Not now

Kostas: Don't work it (he means don't run the program), Mary!

Mary: I am not working it

Kostas: Good!

Mary: Well… compound… ricewater…

Kostas: Ricewater, that's good! Let's join these two

Mary: A solution is…

Kostas: …is the…

Mary: …is the… now we will analyze sugarwater

Kostas: Come on!

Mary: Put in the clouds, take one, and write sugar

Kostas: No, no! Write water

Mary: Yes, yes! You are right!

Kostas: Come on, write water there

Mary: Kostas… we should have written saltwater there!

Kostas: Come on, write water there

…………………………………

Mary: Here? Sugar?

Kostas: Sugar

Mary: Well… now?

Kostas: Write rice there

Mary: And now take three, triple relation, we will connect them with sugarwater, water and sugar and we will write "consists of"

Kostas: "Consists of"?

Mary: "Consists of"

Mary: Well water, is a dissolvent, take a cloud, rice is… rice is not a diluted substance… sugar is the diluted substance

Kostas: Yes

Mary: Because rice does not dissolve…

Kostas: We cannot say that about rice since it is a substance that does not dissolve? (he asks the teacher)

Teacher: No, you don't have to

Kostas: Oh, yes!

Mary: Ok, the water is here… no wait we are not finished. We have to explain a basic relation between solution and compounds

Kostas: What?

Mary: I am saying we have to explain a basic relation between solutions and compounds, so take two (she means a double relation)

Teacher: What are thinking about saying?

Incident 15: (1st session)

(While group 1 presents their map)

7:03p.m.

Kostas intervenes from group 3, approaches group 1 and fills in

Kostas: We can put that they are homogeneous.

Teacher: What kind of homogeneous?

Kostas: Homogenous solution

Teacher: Not homogeneous solution!

Kostas: homogeneous compound

Teacher: How will do that?

Kostas: If we put (and he points at the map) solution is…

Teacher: Which means, what will we put there?

Kostas: A homogeneous compound

Teacher: Let's put a window there like you said. What do you think Aris?

(Aris agrees)

Teacher: So we make a complete concept maps

It is clear in the previous incidents (14 and 15), that active learning is enhanced, since children decipher meanings which seems like they had only partly understood previously (e.g. solution-compound), their thought is organized around this particular cognitive area, their creative (divergent) and their critical (convergent) thinking is evolved, since the children speak their minds spontaneously and effortlessly and through negotiation they converge to a mutually accepted proposition. (Kostas, Mary incident 14).

Additionally, the technique of mind mapping in the first session functioned mainly as a diagnostic tool for the teacher and the researchers, while in the last session, it was mainly used as an evaluation tool.

In particular, in the first session the children's knowledge is retraced, around the cognitive area of solutions, as this has been formed after the experimental procedure. The teacher has the chance to diagnose possible misconceptions, (Arnaudin at al., 1984), which hinders the reconstruction of previous knowledge(Vosniadou, 1994) and "render education inconclusive" (Ross & Mundy, 1991) and adjust his didactic methods in order to facilitate the acquirement of new knowledge (McClure, Sonak & Suen, 1999). One such mistaken perception is shown in figure 18, where the children from the 2nd group (Mary, Eleni), although they have included all the meanings in their map, differentiate the identical meanings "homogeneous compound" and "solution". The correction of the map (figure 19), was made after the map presentation in the classroom, with the intervention of the teacher (incident 16). The same method was used to complete the meanings omission by group 3 (incident 16), resulting in the spectacular improvement of the map structure (figure 13 and 14).

Incident 16

7:05p.m. (1st session) (group 2, Mary, Eleni) Mary analyzes her group's meaning map and they have ended up after the previous group presentation, that a homogeneous compound is else called a solution.

Teacher: Kostas it looks like the other one (meaning the map of group 1)

Kostas: Yes it does!

Teacher: So what was missing from the kids (from group1), the girls have put in. It is small, comprehensive, but has it all. Would you like to add something?

In continuing, group 2 tie-up their relations, remanufacturing their map after discussing it with the teacher and the other groups.

Incident 17 (1st session)

7:09p.m. (group3,Kostas-Mary) Mary analyzes the map where the children have put, initially, examples of solutions of a homogeneous and a heterogeneous compound.

Teacher: <u>Can we make things a little more complicated?</u> Let's fill in the solution with what compounds?

Mary: The heterogeneous compounds with the homogeneous ones

Teacher: Which means, what could we do there?

Mary: We could make a relation combining homogeneous compounds with solutions since they are the same

Kostas: Like the girls! (group2)

Teacher: That's it. That's one! What else can we do?

Mary: We can analyze what it is made of

Kostas: Or put which one is the diluted substance and which is the dissolvent

Teacher: That's it! Then tours will be also completed. So you do this, group 2 does the other thing we talked about, we conclude and we restore it.

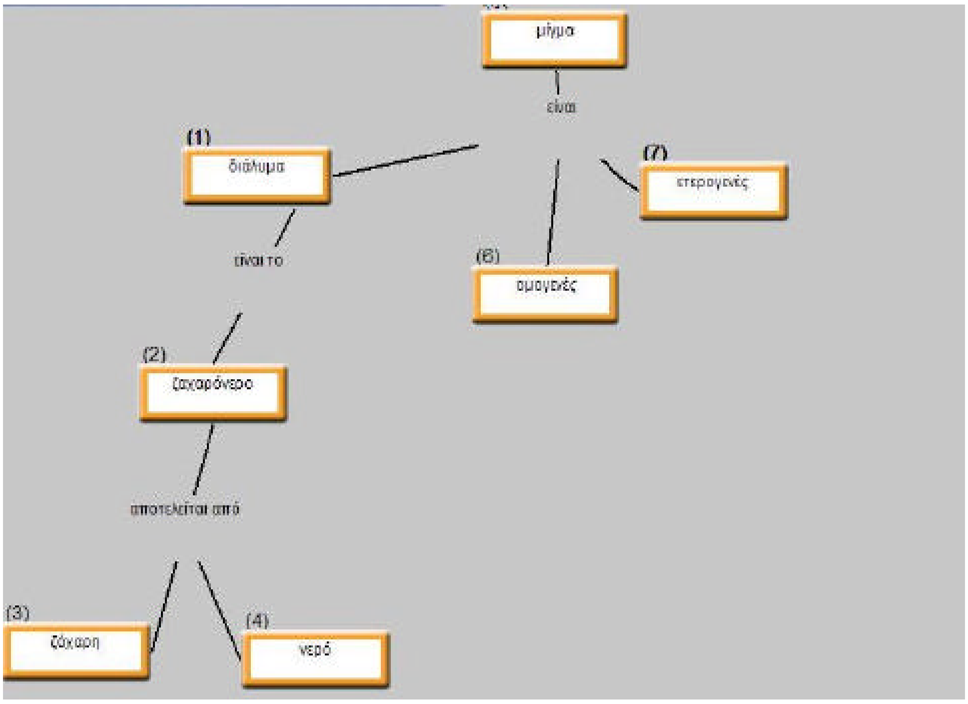


Figure 18: Initial map from group 2 (1st session)

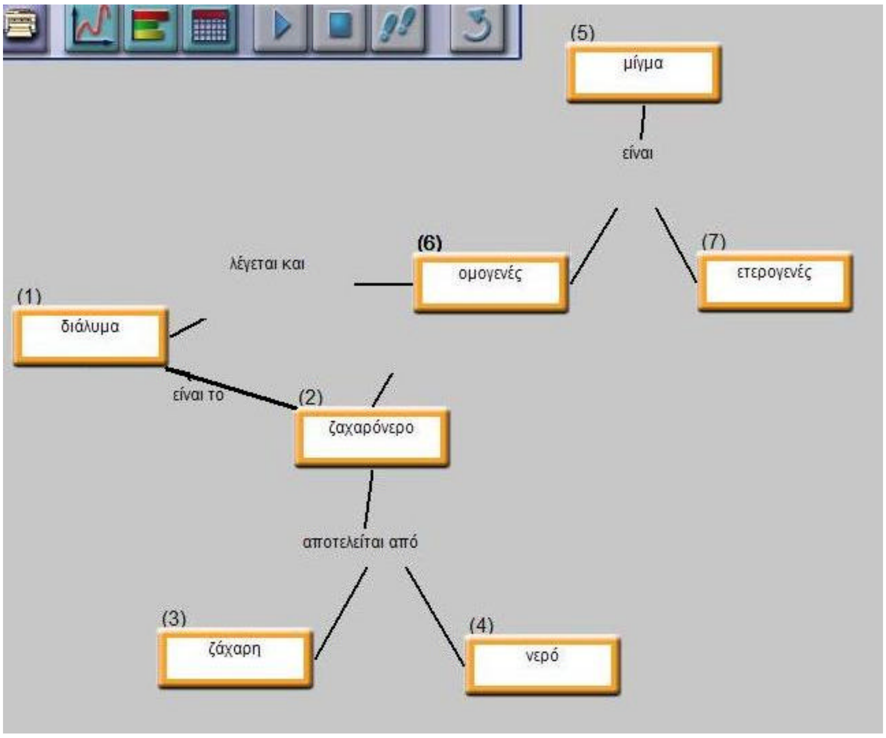


Figure 19: Final map from group 2 (1st session)

In the last session concept mapping played the part of a reliable evaluation tool of this whole teaching intervention, since they represent the children's already formed cognitive structures in the thematic unity of solutions (figure 20).

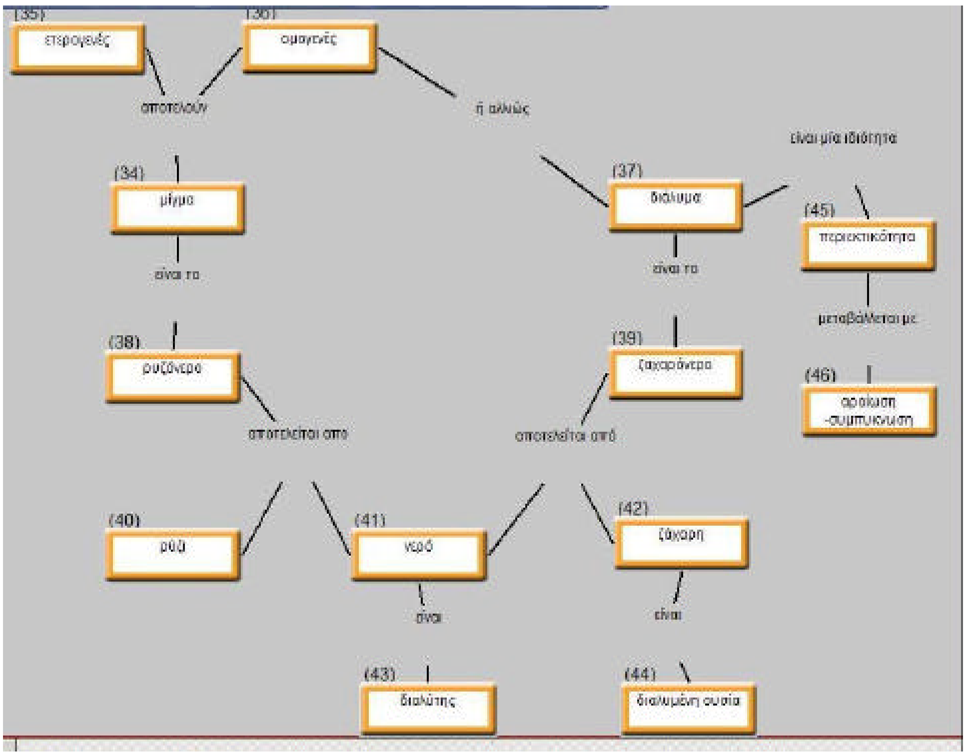


Figure 20: Final map of group3 (6th session)

5.4.9 Conclusions

The main conclusions are presented in relation with the initial case study research questions:

(1) To investigate (a) if children can express themselves using modelling primitives of MS; (b) if children's familiarization with MS basic primitives is possible in a few sessions, and (c) what difficulties spring forth during their interaction with ModellingSpace environment?

During all the sessions, none of the children expressed any inconvenience to the perspective of working with ModellingSpace environment; on the contrary most of them expressed vivid enthusiasm and satisfaction. It is to be mentioned that the activities combined: (a) real experiments with objects, with ModellingSpace based activities, (b) qualitative concepts maps based models, with semiquantitative ones.

Students 12 years old, during the specific learning activities have not presented important difficulties during semiquantitative models creation. The differences with other cases studies presented in this report are due to that:

(d) the distinction between independent and dependent variables was obvious in this case, given that it was directly related to students' causal actions during real object experiments,

(e) the relation of proportionality, in the present case, implicate only two variables and not three ones (there is not a third variable corresponding to the 'constant' of the relation),

(f) the available object oriented entities that could be used were only two, thus the compatibility of values were predicted and regulated by the designers of these entities. Subsequently, students were not involved in this reasoning aspect of clear quantitative nature.

(2.) To identify the intuitive notions as well as the misconceptions of students that are emerged during the corresponding learning activities (related to chemistry), as well as to investigate how they are emerged and how they are evolved during the interaction of young students with ModellingSpace environment and related activities.

During learning activities, well known misconceptions related to the 'Solutions' were emerged, (related to 'dilution of a substance, the existence or the 'disappearance of one of the substances; to the 'homogeneity of a solution, or the solution content'). The expression of these misconceptions in the beginning of a learning activity is an important, necessary and significant 'step' towards the construction of the corresponding scientific concepts.

A clear evolution of concepts distinction and scientific concepts learning has been identified during modelling processes, in the period of six learning activities sessions.

(3.) To explore the significance of qualitative models (concept maps) in relation with simple semiquantitative relations' based models. To investigate the importance of concept map cognitive tool and its role in the learning/teaching process

The depth of the connections of the concept maps produced by children shows an important increase in the final maps, a fact that is proof of better organization and hierarchy of the meanings. Another common feature of the connections in all the maps is that all relations are determined by verbal labels, a fact attributed also to the children's familiarization with the technique of meaning mapping.

As far as the map structure of the concept maps is concerned, this were improved and evolved in more complex and complete forms.

Concerning the content of the concept maps, students decipher meanings which seems like they had only partly understood previously (e.g. solution-compound), their thought is organized around this particular cognitive area, their creative (divergent) and their critical (convergent) thinking is evolved, since the children express them spontaneously and effortlessly and through negotiation they converge to mutually accepted propositions.

Concepts that were explored during semiquantitative models are assimilated to the concept maps at the end of the teaching sessions.

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5.5 Class of a Lower Secondary school (15 years old) working with (a) semiquantitative relations and object oriented entities & (b) quantitative relations.

[author & researcher: Stelios Orfanos, Angelique Dimitracopoulou]

The present case studies report refers to:

- Learning Activities on Physics problems related to Kinematics, where the main involved scientific concepts were: position, time, velocity, acceleration.
- The learning activities and the corresponding students' worksheet, refers to familiar problems to be modeled via semiquantitative relations expressions and then quantitative ones.

They are presented two complementary case studies reports:

- The report of a pilot study focusing on the role of object-oriented entities, their simulation and their effect in learning physics concepts.
- The Global results, from a 12 hours teaching unit, on modeling in physics, using semiquantitative and quantitative relations

5.5.1 Pilot study focusing on the role of object-oriented entities, their simulation and their effect in learning physics concepts.

The case study report presents research results on the effectiveness of a specific category of entities (the object-oriented entities with specific representation of motion variables), to make appear students' misconceptions related to specific concepts (position, velocity as vectorial concepts) as well as their appropriateness to make students ideas evolve to the scientific ones.

5.5.1.1 Pilot study Research questions

(I) Questions regarding the technology based learning environment

- Are the simulations generated by the animation object-oriented based entities realistic?

(II)Questions regarding modelling

- How does simulation help us understand the function of the model?
- How do the representations of quantities help us understand the concepts and the relation between them?
- Does modelling help us link the phenomena of everyday life with real ones?

(III) Questions regarding the content of the activities

The main question of the 3rd pilot research with respect to the content of the activities wishes to explore how simulation through animation contributes to the establishment of scientific content of the concepts of “position” and “velocity”. This question has been divided as follows:

- Does simulation – visualisation through animation help highlight the alternative ideas and conceptual change?
- Do students understand better the scientific content of the concepts of velocity and position?
- Do they interpret the phenomena they meet in everyday life pursuant to physical quantities?
- Do activities help highlight the alternative ideas of students?
- Do activities help students understand the concepts of kinematics in greater depth?
- Do activities contribute to students’ alternative ideas? Do they reinforce them?

5.5.1.2 Research context and conditions

This research took place during July 2002 with a group of 2 students having graduated from the 3rd class of high school. At first place, we tested the activities individually with other students and we further carried out the pilot research focusing the data analysis on a group consisting of 2 students. The research took place in research laboratory so that working conditions were favourable (cool, quiet and friendly environment).

For data collections, we have used (a) the printed worksheets of students , two video recorders: (b) a device registering the computer’s screen while taping the discussions between the team and the researcher; and (c) a video camera. (d) At the end, students were also received questionnaires to fill them in.

5.5.1.3 Participating teachers

The participant teacher was teacher-reseacher, associated with LTEE/Aegean laboratory. No other observer participated in this research. During the experimental phase, efforts were made so as to minimise the participation of the researcher and avoid providing the students with recommendations as to what they should do. Although at first place the students insisted on having the researcher intervening so as to control their predictions or actions, their persistence gradually diminished.

5.5.1.4 Pupils

At the beginning of July (July 4, 2002), phase I of the 3rd pilot research commenced. A group of two students who were friends, had excellent grades in physics and did not have any problem in being recorded and taped for the purpose of the research participated therein. Of course, the researcher committed himself that they would preserve their anonymity; so, the codes “Student A” and “Student B” instead of their names will be used.

Phase I was concluded after two meetings held during two successive days, with each meeting lasting one and half-hour as a whole.

Phase I

During the first introductory meeting, the students were given the purpose of the research and the activities, as well as the differences between research and lessons. Reference was also made to the contributors of the software and the reason of its creation. The students got familiar with the software environment by using a scenario with analogies between a tap and a barrel.

They carried out the activity with the cards and the first of the two worksheets, which refers to kinematics and was included into MS, in electronic form. On the following day, they worked on the second worksheet.

Finally, an interview was held on the basis of the cards and some clarifications were required as for the choices made. Comments were also made by drawing a sketch on the paper as regards the cases in which someone may move on a straight line with respect to the starting point.

Phase II (Final)

The final phase of the research took place on July 30, 2002 with new activities and the final activity with the cards, which the students repositioned.

5.5.1.5 Learning activities

The learning activities were provided to them in printed form. Both the activities on which the students worked and the worksheets had been tested in past pilot researches.

The activities fall under open-ended topics for study and concern an issue of everyday life: the motion of a motorcyclist travelling on a highway.

- In particular, in the context of the first activity, the students are required to position the motorcyclist at various points and answer certain questions regarding the position of the motorcyclist at specific points, his direction and the sign of change of position between specific points.
- The second activity involved questions regarding the simulation of the velocity while the sliders of the moving object's properties had to be adjusted so as to simulate a specific motion (for instance, move rightwards with a constant velocity while starting from a negative initial position). Other activities also took place with models being created.

5.5.1.6 Categories of collected Data

In this research, we increased the kind of data to be used as material for analysis so as to form a much better idea about our questions. The data collected are of the following categories:

(a) video recording of the actions carried out by the students on the computer's screen while taping their dialogues, this procedure lasting three teaching hours;

(b) video recording of the students during pre- and post-tests;

(c) printed material with the students' answers and comments;

(d) interviews at the end of each activity; and

(e) the models saved.

Immediate observation helped us identify the points that need to be further explored, ask clarifications for those points that the researcher could not understand at first glance and form an overall idea about how students think.

Text files figure among the activities with cards carried out by the students. There were cards prior to the main activity, cards after phase I and cards after completion of the activity. The students processed texts in electronic format so we were able to video record them. In other words we have recorded the dialogues between the students and the screen showing the entire procedure: how the students chose and placed cards, their dialogues and arguments.

Analysing the said material was very useful for interpreting the differences noted between the files with the cards before and after a given activity. Likewise, the main activities were recorded.

5.5.1.7 Analysis - Results

5.5.1.7.1 Visualisation of kinematic quantities

The specifications imposed on the visualisation of kinematic quantities were improved following numerous discussions with the contributors of the software and following survey of students. The specifications set forth in this report are the product of discussions with the designers & developers of MS and the survey of students.

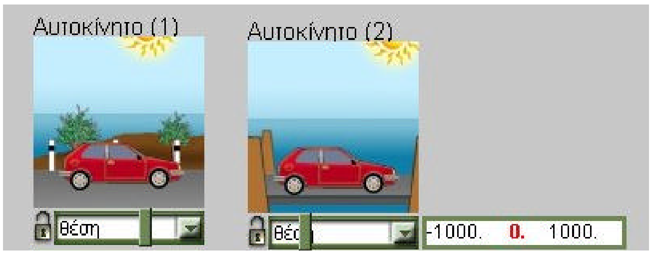


Figure 2.1.11

The starting point, i.e. the point where the position is equal to zero, is highlighted so that the students can understand whether the moving object is at positive or negative positions, to the right or the left of the starting point respectively. It was agreed to show it as a bridge and to indicate the positions to the right or left of the starting point with the background of the picture and the position of the Sun.

In order to show the <u>specifications of the position</u> in figure 2.1.11, we have placed twice the entity at a different position. At the right-hand side of the slider, the picture the car is at the starting point, as shown by the property's values. The background of the picture shows that the car at the left-hand side is at a positive position to the right of the starting point. We think that this is obvious without having to note the cursor of the position. Of course, one could choose to show the values of the position in this entity as well.

The quantity of velocity is indicated by “trails” at the back of the vehicle (figure 2.1.12) and its sign shows the direction of the vehicle.

Figure 2.1.12

The motorcyclist at the left has a negative velocity while the motorcyclist at the right has a positive, smaller velocity.

Acceleration with the same direction as velocity: there are “trails” at the wheels while these leave marks on the pavement. Acceleration – braking is noted when velocity has opposite direction from acceleration and “blurring” of wheels (figure 2.1.13).

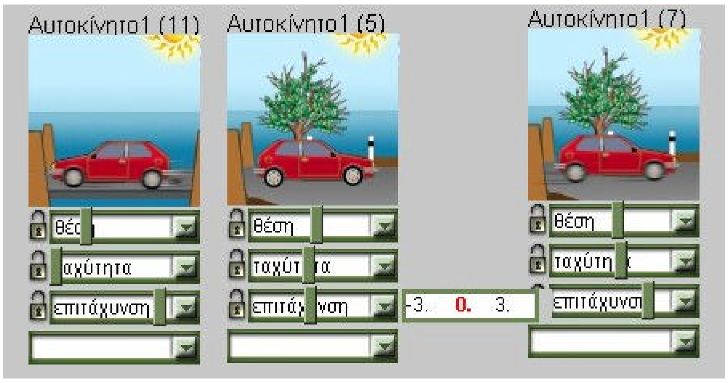


Figure 2.1.13

Each quantity is simulated separately but the combination of quantities is also simulated. Figure 2.1.13 shows the simulation of the quantities’ combination for the middle car where there is no acceleration and wheels have no blurring. As for the car to the left, acceleration is opposite of velocity, so we have braking and the wheels blur on the pavement and at the back of the car. As for the car to the right, we have acceleration with the same direction as the velocity, so the wheels are blurred and leave marks on the pavement.

Simulations enable students to notice and explore physical phenomena that are difficult or impossible to be explored by means of experiments. They can study the consequences of a considerable number of changes under experimental conditions within a short period of time. Researchers conclude that the educational environments based on simulations, through the appropriate seminars and teaching approaches, help students overcome the cognitive difficulties that are due to their misconceptions, and can improve their alternative ideas (Trowbridge et al. 1999, de Jong, et al.1999, Jimoyiannis & Komis 2001).

It should be noted, however, that the models generating simulations are subjective to a certain extent since they are based on the personal choices of the programme's designers. In addition, students carrying out simulated experiments may reinforce their own semi-intuitive ideas instead of being led closer to acceptable scientific theories (Clement 1989, Dimitracopoulou 1999).

We found it necessary to explore the contribution of simulation before proceeding to the main research. By carrying out this pilot research, we wanted to draw explicit information about the way students utilise the software, how they structure different concepts and how they develop their reasoning, in order to:

a) ascertain how and where each software contributes and whether it gives rise to additional difficulties;

b) deduce detailed and explicit information about the students' ideas, reasoning and behaviours so as to organise the worksheets of activities for the main research. The results we will present focus on the contribution of simulation.

5.5.1.7.2 Cards: Pre- & post-tests

Pre- and post-tests were used so as to check and analyse the contribution of the activities to the deeper understanding of the concepts. These tests had the form of a text file. They consisted of two parts.

The upper part includes the terms of concepts of kinematics such as "Velocity", "Change of velocity", "Positive velocity", etc, while the lower part includes a large number of text boxes-cards such as: "the moving object changes position", "it moves slowly", "it moves rightwards", "it starts up", etc. During the tests, students were required to match the phrases-cards with the concepts of kinematics. The classification made by the students prior to the activity is shown in figure 2.1.14.

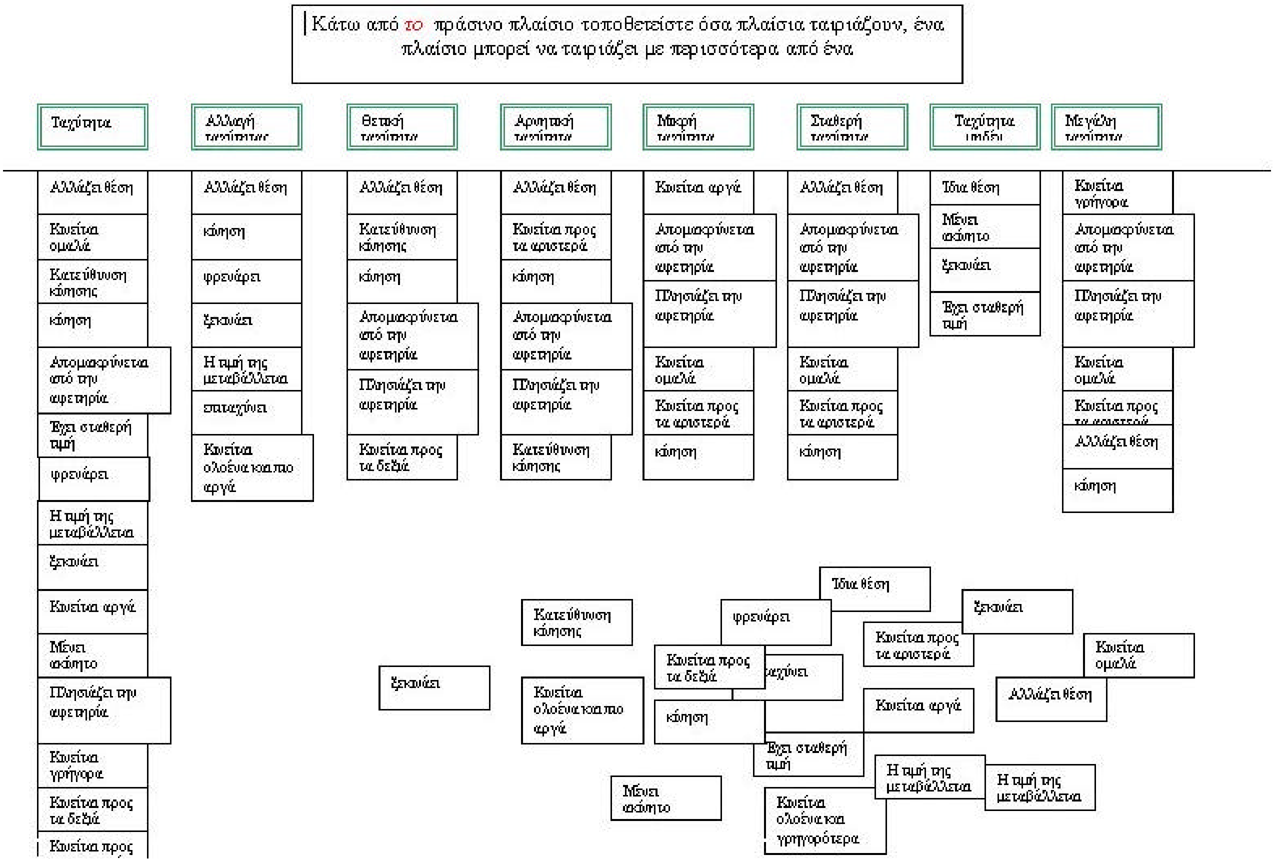


Figure 2.1.14

There were some cards the students believed that they did not match with any of the concepts above the line and were left at the initial position. These are at the lower part of the sheet. The same test was given to the students after the end of the activities with the software (post-test), approximately one month after the initial test. The classification of concepts – cards is given in figure 2.1.14. The entire procedure was video-recorded so as to enrich the experimental data with the oral explanations provided by the two-student groups during tests.

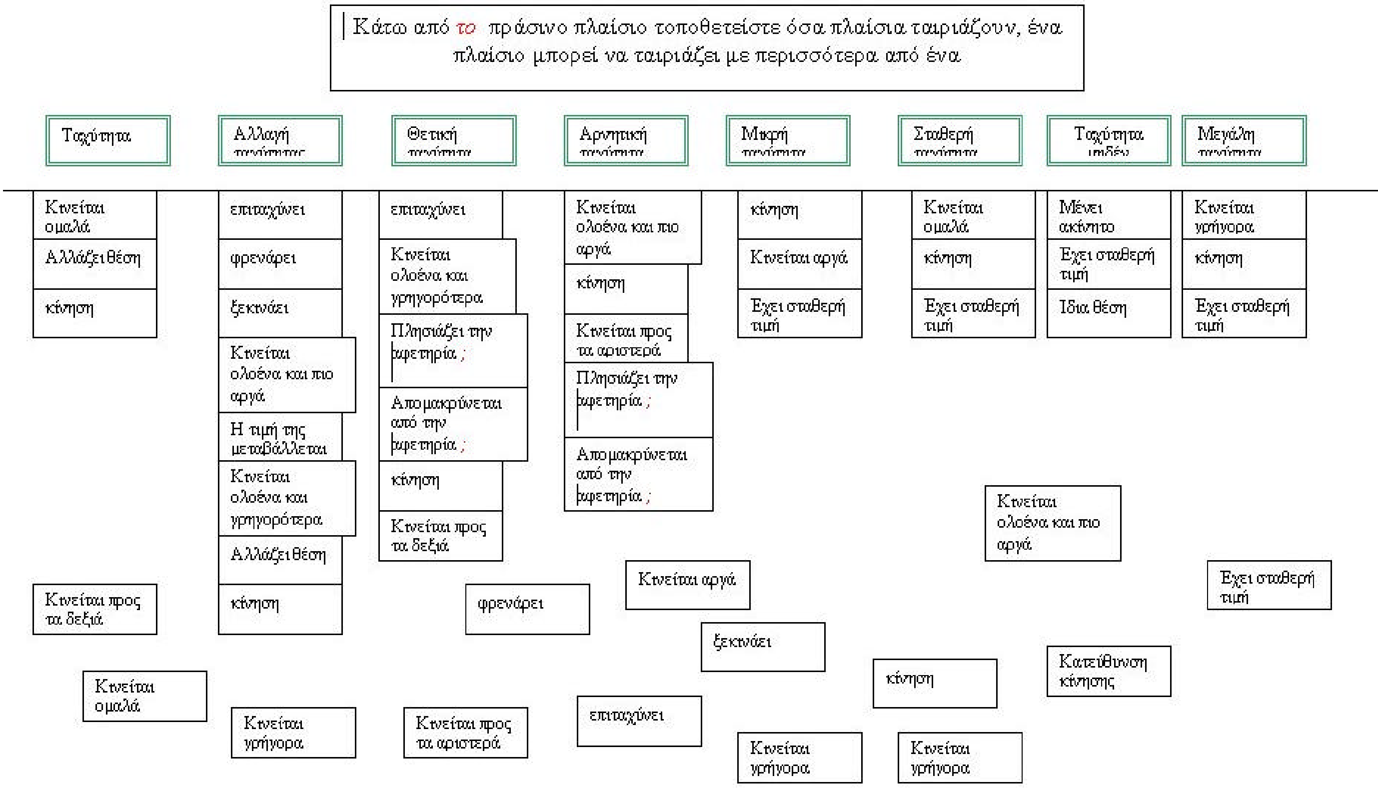

Κάτω από το πράσινο πλαίσιο τοποθετείστε όσα πλαίσια ταιριάζουν, ένα πλαίσιο μπορεί να ταιριάζει με περισσότερα από ένα
Ταχύτητα
Αλλαγή ταχύτητας
Θετική ταχύτητα
Αρνητική ταχύτητα
Μικρή ταχύτητα
Σταθερή ταχύτητα
Ταχύτητα μηδέν
Μεγάλη ταχύτητα
Κινείται ομαλά
Αλλάζει θέση
κίνηση
επιταχύνει
φρενάρει
ξεκινάει
Κινείται ολοένα και πιο αργά
Η τιμή της μεταβάλλεται
Κινείται ολοένα και γρηγορότερα
Αλλάζει θέση
κίνηση
επιταχύνει
Κινείται ολοένα και γρηγορότερα
Πλησιάζει την αφετηρία ;
Απομακρύνεται από την αφετηρία ;
κίνηση
Κινείται προς τα δεξιά
Κινείται ολοένα και πιο αργά
κίνηση
Κινείται προς τα αριστερά
Πλησιάζει την αφετηρία ;
Απομακρύνεται από την αφετηρία ;
κίνηση
Κινείται αργά
Έχει σταθερή τιμή
Κινείται ομαλά
κίνηση
Έχει σταθερή τιμή
Μένει ακίνητο
Έχει σταθερή τιμή
Ίδια θέση
Κινείται γρήγορα
κίνηση
Έχει σταθερή τιμή
Κινείται ολοένα και πιο αργά
Έχει σταθερή τιμή
Κινείται αργά
Κινείται προς τα δεξιά
φρενάρει
ξεκινάει
κίνηση
Κατεύθυνση κίνησης
Κινείται ομαλά
Κινείται γρήγορα
Κινείται προς τα αριστερά
επιταχύνει
Κινείται γρήγορα
Κινείται γρήγορα

Figure 2.1.14

Place the corresponding cards below the green one. There is not number limit. Some cards may correspond to more than one time.

Velocity	**Velocity change**	**Positive velocity**	**Negative velocity**	**Small velocity**	**Constant velocity**	**Zero velocity**	**High velocity**
uniform motion	It accelarates	It accelarates	It is moving faster	motion	uniform motion	It is not moving	It is moving fast
displacement	It is braking	It is moving faster	motion	Slow motion	motion	constant value	motion
motion	It is starting motion	It is approaching the reference point;	It is moving to the left	constant value	constant value	Same position	constant value
	It is moving slower	It is drawing away from the reference point;	It is approaching the reference point;				
	The value is changing	motion	It is drawing away from the reference point;				
	It is moving faster	It is moving to the right					
	displacement						
	motion						

It is moving slower

Slow motion

constant value

It is moving to the right

It is braking

It is starting in motion

motion 's direction

motion

It is moving constantly

It accelarates

It is moving fast

It is moving to the left

It is moving fast

It is moving fast

***Figure*: Cards-based pre -test, [group of students G1]**

Place the corresponding cards below the green one. There is not number limit. Some cards may correspond to more than one time.

Velocity	**Velocity change**	**Positive velocity**	**Negative velocity**	**Small velocity**	**Constant velocity**	**Zero velocity**	**High velocity**
displacement	displacement	displacement	displacement	Slow motion	displacement	Same position	It is moving fast
uniform motion	motion	motion 's direction	It is moving to the left	It is drawing away from the reference point;	It is drawing away from the reference point;	It is not moving	It is drawing away from the reference point;
motion 's direction	It is braking	motion	motion	It is approaching the reference point;	It is approaching the reference point;	It is starting motion	It is approaching the reference point;
motion	It is starting motion	It is drawing away from the reference point;	It is drawing away from the reference point;	uniform motion	uniform motion	constant value	uniform motion
It is drawing away from the reference point;	The value is changing	It is approaching the reference point;	It is approaching the reference point;	It is moving to the left	It is moving to the left		It is moving to the left
constant value	It accelarates	It is moving to the right	Motion orientation	motion	motion		displacement
It is braking	It is moving slower						motion
The value is changing							
It is starting motion							
Slow motion							
It is not moving							
It is approaching the reference point;							
It is moving fast							
It is moving to the right							

Same position

It is starting motion

It is braking

It is moving to the left

uniform motion

motion 's direction

It is moving to the right

ccelerates

displacement

It is starting motion

It is moving slower

motion

Slow motion

constant value

The value is changing

The value is changing

It is not moving

It is moving faster

***Figure:* Cards -based Post-test, [group of students G1]**

Table 1: Summary of cards related to the Velocity

Concept of velocity		Before	After
Application	**Kind of motion**	Just constant-velocity motion	Constant-velocity Changing
Expression	**Value = zero**	-	Remains still
	Vector content	No	Yes
Organisation	**Number of correlations**	3	15
	Correlation with the change in position	Yes	Yes
	Correlation with the change in kinetic condition	No	Yes
	Correlation with acceleration	No	Yes

Table 2: Summary of cards related to the Velocity

Conceptual change	Before	After
Sign of velocity `	Confused with acceleration	no
	Confused with algebraic value	no
	Link with the direction of motion	Link with the direction of motion
	Doubts as to remotion or approach of reference point	They answered with certainty
Confusion about velocity-position	It moves toward the starting point Defined by position	They clarified what defined each quantity with specific arguments
Correlation with acceleration	No	Yes

5.5.1.7.3 Analysis of students expressions from both Pre- & post-tests / cards & oral justifications

The analysis of the results was based on the interaction of students with the software and the interaction within the group as well as on the answers and explanations given during the tests.

Note that in order to interpret the results during pre- and post-tests, we took as indicator of the understanding of concepts the extent to which students can define a concept in an acceptable functional manner and distinguish the same from relevant and different concepts. Throughout the study of activities, a measure used for understanding a kinematic concept was the extent to which a person applies successfully this concept in order to interpret simple motions of real objects noticed in everyday life (Trowbridge, David & McDermott, 1980).

5.5.1.7.3.1 Alternative ideas

Many times, students give correct answers or perform activities without, however, having fully understood the content of concepts. Yet, they maintain alternative ideas as well.

More specifically, as regards the activity with the cards, they placed the card "it moves rightwards" under positive velocity, believing that the sign of velocity is determined by the location of the motorcyclist as to the starting point, i.e. rightwards or leftwards, and not as to the direction of motion. This resulted from the analysis of the entire research because the comparison of the documents with cards did not suffice.

In the final activity with the cards, they no longer link the sign of velocity with the change. The cards *"accelerates", "moves increasingly slowly" or "moves increasingly faster"* do not exist under positive or negative velocity.

As stated before, the instructors could not always detect easily the students' alternative ideas or their understanding, because they linked "positive" with "rightward motion" as regards velocity, but they considered the issue statically as it occurs with position and not with direction.

Another alternative idea of the students was deduced from this research: the quantity that is further to the left has a lower value whereas the correct answer would be lower algebraic value. However, they easily changed this idea when they chose the indication of values and saw the respective values together with the position of the property's cursor.

Another alternative idea came up, namely at the reference point velocity is equal to zero. This resulted when they were trying to find the picture with the motorcycle on the bridge, that is at the place where the value of position is zero, by displacing the cursor of the velocity (as if it were a reference point for velocity). Of course, they did not find this picture and the opportunity was offered to explore this idea and another relevant idea that resulted from another question: the velocity depends on the position. The visualisation of velocity with the trails that remained the same when they attributed the highest value to velocity for all positions made them seriously think about the issue and interact, thus getting closer to the correct viewpoint in terms of physics:

"No, but do you know, put it a little backward, you see velocity is this again. Go back a little further. No matter where you take it (he refers to the cursor of the position) due to velocity, it is the maximum velocity".

In other words, they understood that the velocity of the moving object –indicated as "*You see velocity is this again*" and meaning the trails shown due to motion—is determined by the value of the velocity and not by the value of the position.

The alternative idea that "positive velocity" means "accelerate" was deduced from main activities too. Student B answered that wherever the cursor of the velocity is totally to the right, the motorcyclist accelerates although the same student knows or directly answers what acceleration means (changes velocity). It is striking that the student continues to say the same thing about the position of the velocity's cursor, when the cursor is totally to the left. The answer he gives to his fellow student is worthwhile noting because he answers by making the hypothesis:

"Yes, due to the shape, if the shape continued, he might keep on accelerating or decelerating".

This specific answer was considered to be a step toward the full understanding of positive velocity and, in general, of the role of the velocity's sign because after the final activity with the cards, they did not place any cards indicating change under the positive or the negative velocity.

5.5.1.7.3.2 Understanding & constructing scientific concepts

It was deduced from the greater number of cards placed under the concept of velocity following the main activities that the students understood better the concept of velocity and also enriched its content. The same was established from their dialogues. For instance, when they were asked to have velocity equal to zero, they said:

"*Where it is still. Yes, right where it starts up, man", "it can't possibly start up now*"

so as to place it under the positive velocity although in the end they did not place it. Notwithstanding, it seemed that they had understood it.

Prior to the activities with the concept of positive velocity, they believed that this has two meanings. First, the moving object is to the right of the starting point and, secondly, it accelerates, this having the meaning of increased velocity, as it arose from the activity with the cards beforehand, where they chose the card "increasingly faster".

During implementation of the activity in the model generator, after the property of velocity was chosen so that the motorcyclist has two properties, i.e. position and velocity, they instantly observe the following:

- the motion of the motorcyclist may have the opposite direction;
- the direction of the motorcyclist's motion depends on the sign of velocity;

♦ they match the correct cards: “positive velocity” with “moves rightwards” and “negative velocity” with “moves leftwards”.

While trying to match the card “goes away from the starting point”, the students disagreed. Student B, in order to convince student A, put forward two alternative ideas as his argument. At least one of these existed in both of them:

"In order to have negative velocity, you have to decelerate", and the other one "*the fact that we have come close to the starting point has nothing to do with velocity*". As a result, B persuaded or confused A saying: “*when you pass the starting point, you have constant velocity*” (you neither decelerate nor accelerate). This is why, prior to the activity, they put a question mark to the cards, since B did not fully convince A. Yet, they did not want to remove such cards.

It resulted from this and other dialogues held before the main activity that their arguments were based mainly on the definitions and the content of concepts and not on examples with motions from everyday life.

In the first question of activity No 3 (fast rightwards), an issue with a combination of alternative ideas came up. If the velocity depends on the position, as shown before, which quantity determines the rightward motion? Would it be velocity or position? Yet, it should be noted that in past activities they easily gave an answer to what positive velocity means. The visualisation of the properties separately helped them arrive at the answer that complies with the theory.

The fact that they finally understood the concept of positive velocity to a large extent is deduced from the following argument used in the final activity with the cards. When they placed the card “approaches the starting point” under positive velocity, they said: “*if you have positive velocity, you may move both slowly and fast*”.

Although they did not manage to give an explicit answer to the question of the 3rd activity (fast rightwards), it subsequently became evident from their direct answers that they understood which quantities determine what; that velocity determines both “fast” and “rightward” motion and that if they apply a value to velocity, this will be independent from the position.

The visualisation highlights the dynamic content of kinematic concepts in opposition to the static content of the book and helps students cope with difficult situations, as shown from the following dialogue:

> "*You agree (B) that velocity depends on position. But I got confused as to what it is. Because, you know, you can see in the figure that no matter where you take the cursor of the position, the velocity and the shape show that it is the same. You see, it’s everywhere.*"

5.5.1.7.3.3 Metacognitive skills - Argumentation

Let us compare the arguments of the same student 25 days after this meeting for the activity with the cards. As regards the same topic, i.e. to match the same cards, he used the following argument: "*because if you move from a negative value toward the starting point, you approach it and you have positive velocity*". The following are deduced from the above argument, the activity with the cards and their answers to the interview:

- ♦ The student has made clear what position and what velocity determine respectively. He means here at the position, left to the starting point. Positive velocity means "rightward direction" and given that he was before the starting point, he moves toward it.

They placed under both the positive and negative velocity the cards "it approaches the starting point" and "it gets away from the starting point" so as to cover all combinations, thinking that the moving object may be at either positive or negative position. This was a general activity.

He argued by giving an example with him being the moving object and linked abstract concepts with real motion from everyday life.

5.5.1.7.3.4 Scaffolding activities

Wherever the questions of the activities were more demanding, we saw that they did not give a direct answer but they needed to make more tests, interact between them to a greater extent (with longer dialogues) and also comment on the visualisation: "Not exactly like this because it does not move away from it". He moved away from the starting point, he initially displaced the cursor of the velocity and by means of the picture the student saw that the motorcyclist did not move away. Then, the other student said that the cursor of the position should be displaced rightwards…

Interaction between them and the support of their argumentation become easier.

They find obvious what is shown in the visualisation (direction was shown in this case).

They carry out much easier the activities referring to one property. For instance, they instantly answer the question whether the motorcyclist is still or not.

5.5.1.8 Summary of results from this pilot research

5.5.1.8.1 Answers to the questions related to the software

- ➢ The simulations created by the animation based object-oriented entities are realistic and understood by the students.
- ➢ The way in which semi-quantitative relations are symbolised is also comprehensible. It is worthwhile noting that the time of students' familiarisation in this research was by far less than 15 minutes while both familiarisation and the activity itself took place during the first activity.

5.5.1.8.2 Questions related to the content of activities

Further, we present in brief the main findings of the pilot research classified in four main categories:

A. A set of alternative ideas of the students was stressed with respect to the concepts of position and velocity:

- Velocity is zero at reference point: "*when you pass the starting point, you have constant velocity*".
- The values of the property being further to the left are lower.
- The sign of velocity expresses for students the following: (a) where the moving object is located in relation to the starting point. They linked the positive sign with rightward motion but examined it in a static manner, as it occurs with the position (where it is), and not in terms of direction (where it goes); (b) the change in velocity: «*…if you have negative velocity, this means that you decelerate*»
- Confusion between the content of velocity and position. The velocity depends on the position of the moving object «*…yes, but the fact that it moves (at a certain velocity) rightwards means that it is also a question of position*»

B. Contribution to the conceptual change was noted: The activities helped the students interact so as to cope with difficult situations and also played a role in the following:

(a) they highlighted the dynamic content of kinematic concepts (in opposition to the static representation of books); and

(b) students understood the sign of velocity and disassociated (differentiated) it from the change in velocity as well as from the position of the moving object in relation to the starting point.

C. Contribution to the verbal interaction between the students was noted: The activities with the software in conjunction with the proposed topics for study promoted interaction between the students and mainly the expression of their ideas (through prediction, explanation and argumentation procedures).

D. Contribution to a deeper understanding of the concepts of velocity and position was noted, as shown from the comparison between pre-tests and post-tests. It became evident that the students enriched the content of the concept of velocity, understood and distinguished what velocity determines and what position. It resulted from the initial dialogues (prior to the main activity with the software) that the students' arguments were mainly based on the definitions of concepts, they could not link them with specific examples and were not able to answer the questions. If we compare the arguments of the same student 25 days after the pre-tests, we note that he used specific examples with moving objects (personalising the motion) and linked abstract concepts with real motion taken from everyday life. This fact enabled him to reason out difficult questions and verify his conclusions.

Note that students can answer immediately questions related to one variable much easier (e.g. whether the motorcyclist is still). Wherever questions involve more than one variable, we notice that they have to make more tests with the educational software and discuss between them to a greater extent. Considerable improvement was also noted in the activities with objects moving with constant velocity. As regards the activities involving moving objects with acceleration, the results were less satisfactory, since simultaneous distinction between the change in position and change in velocity over time requires more advanced thinking skills (higher school class).

Summary of conclusions

Many times, students give a correct answer or solve problems of school textbooks, without having fully understood the content of concepts. At the same time, while they have been taught the respective sections, they keep alternative ideas that the instructors cannot always detect easily.

The simulation through animation – representation of a real object-- seems to play a significant role: at first place, it stresses the students' alternative ideas and it furthers structures the content of vector concepts like those of velocity and position after a short processing period.

5.5.2 Global results, from a 12 hours teaching unit, on modeling in physics, using semiquantitative and quantitative relations

[Author, Teacher-Researcher: Stelios Orfanos & Angelique Dimitracopoulou]

The case study report presents research results on the following:

(A) (a) understanding of representations: table of values and graphs , (b) modeling process, (c) teaching strategies

(B) The contribution of MS environment and worksheets on learning concerning: (a) the construction of a structured network of concepts, (b) the relations among specific concepts, (c) the distinction among independent and dependent variable, (d) the relation of proportionality, (e) the notion of a 'constant variable', (f) misconceptions and their evolution related to the concept of velocity, and the concept of position (g) students difficulties when they construct algebraic models.

Most of the actual research related to the modelling environments for learning purposes, focuses on modeling process, or on scientific laws discovering or validating [5]; [6];[7]; [11]; [12];[13]; aspects that are significant. However, there is a lack of research that shows the possible modeling activities contribution on scientific concepts' understanding, as well as on the effects of the representation of modeling primitives (that each system support) to the students' conceptualization [3], [14].

In sciences, 'concepts' function as structural elements of the cognitive edifice. In the scientific theory, a concept relates to others via axioms, definitions and/or laws, the network of which, constitutes the organisation of the concept. In the mind of the students, the concepts are feebly structured and partial. However, a concept conceived in isolation is practically without meaning and useless. Most students think of Physics as a collection of facts that have to be memorized. This tendency weakens their ability to discern the beautiful structure of the natural world that science reveals to us [4].

In traditional teaching a lot of significant concepts are introduced with a sequence that does not provide the students with all the necessary information required to comprehend. We consider that understanding concepts and the relations among them is greatly facilitated by the use of modelling tools [15], taking into account that the modelling process forces students to change their vague, imprecise ideas into explicit causal relationships [9].

The aim of this report is to present briefly some of the results of our investigation into modelling activities related to kinematical concepts.

The MODELLINGSPACE enables students to build their own models and offers the choice of observing directly simulations of real objects and/or all the other alternative forms of representations (tables of values, graphic representations and bar-charts). The students -in order to answer the questions- formulate hypotheses, they create models, they compare their hypotheses with the representations of their models and they modify or create other models when their hypotheses did not agree with the representations. It is to be noted that one of the specificities of MODELLINGSPACE rises on the fact that incorporates multiple modelling modes and a wide range of entities and variables (from the most concrete to the most abstract ones). Moreover, it supports various representational forms, and allows the expression through the greatest visualisation, combining the modelling tools with real world simulations (not only abstract ones) [2].

5.5.2.1 Research Context & Conditions

The aim of the research was to study how the modeling activities help students attain a scientific understanding of alternative concepts and of the relationships among them. The research was carried out with a sample of 12 Greek students aged between 14-15.

The students worked in teams and performed worksheet-based-activities, during 6 sessions of 90 minutes each one.

The teacher of these students are teacher-researcher associated with the LTEE/Aegean laboratory.

The students & the teacher belong to the Venetokleion Gymnasioum (high School) of Rhodes.

5.5.2.2 Learning Activities

The subjects of the activities were specifically designed to be comprehensible to students from 15 to 16 years old [2]; [15]. The learning activity corresponds to the scenario "In the national Road" (presented into the D5: Learning Activities Deliverable". Author of the activities is the teacher of the class (Stelios Orfanos).

The worksheets are designed in such a way so as to enable the students to elaborate on the proportions at issue via situations of modelling. The tasks assigned to the students require them to reason first qualitatively, then proceed semi-

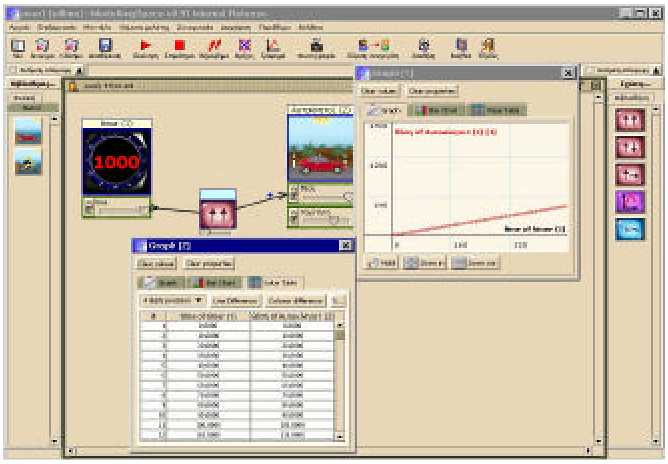


Figure 1 Snapshot of a semiquantitative model

quantitatively and finally develop a fully quantitative reasoning.

5.5.2.3 Categories of collected Data

In this research, we increased the kind of data to be used as material for analysis so as to form a much better idea about our questions. The data collected are of the following categories:

(e) video recording of the actions carried out by the students on the computer's screen while taping their dialogues, this procedure lasting three teaching hours;

(f) printed material with the students' answers and comments;

(g) interviews at the end of each activity; and

(e) the models saved.

Immediate observation helped us identify the points that need to be further explored, ask clarifications for those points that the researcher could not understand at first glance and form an overall idea about how students think.

5.5.2.4 Overview of Data Analysis

The data analysis were based mainly on the re-transcriptions of video based data. Given that the translation of students dialogue extracts (from the Greek language to the English one) is known that it is very difficult, given that it remains the risk to change the meaning of students expressions, we present in this report only the overview and the results of data analysis. The presentation of data analysis into the following sections concerns only a few of the research questions.

The data analysis and the derived results and conclusions, from the present case study concern the following:

A)

- **Familiarisation**
- **Teaching management**
- **Modelling process & teachers**
- **Understanding of representations: graphical representation – value list**
- **Contribution of simulation**
- **Model testing**

B)

- **Organised conceptual framework**
- **Relation between quantities – function**
- **Distinction between independent and dependent variable**
- **Proportion relation**
- **Constant function**
- **Alternative ideas, misconceptions**

- **Understanding of quantities – relations – formulas – laws**

5.5.2.4.1 Familiarisation

Familiarisation with the software was achieved within a short period of time. At first place, the students got familiar with its operating mode and, subsequently, with separate functions and the tools requiring more advanced cognitive functions such as the adjustment of the constant or the editor of quantitative relations. We did not press them to learn the terminology used in the software, which is brand new for them. We preferred explaining the unknown concepts when they found them for the first time or asked questions about them.

We noted phenomena where the students had a certain difficulty and could not advance or where they followed a course other than the one described in the handout. In such cases, the instructor plays a decisive role since he can intervene appropriately, as the case may be. The more the students got familiar with the software the less the instructor had to intervene so as to answer queries regarding the use of the software.

5.5.2.4.2 Teaching management

Modelling – Relation of students, level of knowledge they have

Modelling procedure in the environment concerned is easy without requiring any special skills. Students being 14 years of age easily create models and have no problem in modifying or deleting them. As for the first activities, they prefer supplementing their model instead of deleting it, even though it becomes more complicated. Initially, the students read hastily the questions and did not pay great attention to the handout; they focussed more on the computer screen. Many times, they were advised to read carefully the questions and then turn to the modelling tool.

Interest - Motive

The activities capture the students' interest wherever difficulty is increased in the problematic situations given to them for solution. In the opposite case, i.e. when they deal with known issues, they treat them as routine. In certain cases, when they focus on specific situations, they make greater effort to understand the phenomenon and ask for clarifications about issues with which they would not cope in a different case. Attaining a goal satisfies them and boosts their morale so as to proceed to the subsequent questions. On the contrary, when they cannot advance and achieve something, they are disappointed and discouraged.

Variety of representations - Understanding

The representations of the model stimulate students to explore things and make their thought easier, while helping them develop strategies, interact and answer the questions. With the tests, they confirm or reject their ideas and progress by discovering things.

The simulation captures their interest and motivates them to deal more with an issue without getting bored or disappointed. In certain cases, we noticed that the students are impressed by the result they see in such simulation due to the changes they bring to their model. By using the traditional teaching aids, they cannot directly have the respective result. In other cases, the simulation puzzled them and they tried to interpret the result.

Model prediction – Testing – Understanding - Interpretation

Wherever students make predictions, even if these are not correct, they understand better the model and the representations, interpret them and answer the questions. The existence of predictions contributes to the interaction between students and gives rise to comments. On the contrary, wherever no prediction was available, a lack of material was noted that could serve as reflection basis for further understanding. Wherever their predictions coincide with the representations of the model, the students are evidently satisfied.

Wherever students make predictions, they use constant-velocity motion as reference point for the purpose of comparison with other motions. There are, however, things in constant-velocity motion that they have not fully understood.

Many times, students learn formulas because they believe that these are the most important things. There were students who knew the formulas but could not give an answer to various questions such as forming a quantitative relation in the model, even though they had chosen the correct entities and properties they needed.

Study of handout

We noticed quite frequently that students read the handout superficially or partly and then turned to the software without following its questions. We coped with this problem to a great extent subsequently, since we did not give them the entire handout of the activities but page by page, together with instructions so as to have them read the handout thoroughly. Wherever students found questions with many sub-questions, they answer some of these but not all. Thus, we took this fact into account in the following activities.

Behaviour of the groups : Between students

We distinguished certain behaviours in the groups. At first place, they were competitive but then became more co-operative between them so that a team spirit started being established. In many cases, constructive discussions took place. One student asks questions to the other and they proceed so as to better understand the model and, thus, give a solution to the problem they face.

They avoid dealing with something that is or believed to be unknown. They answer «I don't know» and feel the need to apologise for that, or they reply more smartly «I don't remember».

Behaviour of the groups: Between group and teacher

Students need to feel that the teacher assists and stands by them, especially in those environments with which they are not familiar.

Although they needed help from their teachers, they managed to give an answer to their questions by themselves and correct both their predictions and views, which they had initially named remarks, by testing their model.

On many occasions, the researcher intervened in a decisive manner. Without guiding them, he recommended them to change values, test the model and notice the representations. In other cases, the researcher tried to help them by asking them questions.

5.5.2.4.3 Students & modelling process

Model creation - modification

There are many times when students create correct models but not as regards the motions described in the worksheets. The teacher asked them questions so as to help them understand that the handout referred to a motion other than the one created in the software. Wherever the results generated by their models coincide with their predictions, they answer triumphantly.

The students being at this age, namely 14-15 years old, cannot model motions consisting of consecutive phases. They could carry out activities with motions of this type by using exploration models.

Link with relation - adjustment

Initially, the students believe that the creation of a model lies in connecting the properties they have selected with one of the relations. As activities progress, they realise that the creation of a model does not lie solely in the connection with a relation. As regards the models of semi-quantitative and quantitative reasoning, it lies in the "adjustment" of the relation and in the creation of the relation respectively.

Representations - simulation

Simulation holds their interest so as to deal more with the issue, reflect on the same and, even if they cannot give a solution, make changes and notice the different results that become the object of discussion between them or with the teacher. Otherwise, in the event of conventional activities where students cannot have any simulation, their interest usually wanes and they start getting bored or even disappointed if they cannot solve a problem. By making certain changes, they noticed different results that made them wonder and discuss the same between them or with the researcher. There were times when the groups paid more attention to the simulation than to the representations of the model or vice versa. In certain activities, some groups focussed more on the simulation than on representations.

Repeating the test of the model helps students pay greater attention to both the simulation and the representations of the model. Wherever students wanted to focus on certain representations, they moved, showed, maximised or hid windows –by taking advantage of the capabilities of the software—depending on which points they focussed. These remarks contributed positively to the understanding of a quantity's evolution over time.

The representations of the model raise issues to be explored and facilitate their thought and strategies so as to answer questions arisen and solve a given problem.

Modelling strategies

The existence of the different types of representations, simulation and model running mode gives rise to reflections, predictions, tests, ideas and strategies.

Reality and model

Students think that the pictures of the entities and their respective simulations are realistic while sometimes they wonder whether what they observe on the screen can also happen in reality. This puzzlement refers to phenomena they have not been taught at school. As deduced, they believe that what they have been taught as phenomena also happen in reality.

Control of the model - Test

During the initial activities, they believe that their model functions like the real phenomenon. They treated the modelling tool as simulation tool, although they had not used such software at school. They wonder whether they use it properly or whether they had not understood it fully but they do not think that the model is not integrated.

Students check the model by having recourse to simulation or to its representations.

Reasons for discussion

Teacher – students' groups

The environment favours the creative dialogue between students and the instructor. It stimulates the instructor to pose new questions and gives rise to issues that arouse the interest of students for further exploration or discussion.

On many occasions, the activities do not suffice to help students understand the phenomenon in depth. It is the instructor who will observe and check whether students have thoroughly understood the phenomenon by asking the right questions.

Interaction between the group

Students interact. Originally, the questions of the activities and subsequently the tests by means of the models they create or modify give rise to discussion between students. There are many times when students discover answers by interacting without the assistance or intervention of the researcher.

5.5.2.4.4 Graphical representation – Value list

Using the tool of graphical representation

Students use easily the tools of the software for creating graphical representations as well as the change in the scale of axes. It turned out to be not only easy but also entertaining.

Axes may change during these operations with which students need to get familiar. In the last versions, the tool used for creating graphical representations has been considerably modified and is user-friendlier.

Understanding the graphical representation

Modelling activities help students read the graphical representation, better understand the diagrams and discover other quantities included therein, in addition to the quantities corresponding to the axes. For instance, they managed to link the slope of the position-time graph with the quantity of velocity and the constant of proportion.

Prediction

It is important to have students make predictions about the form of graphical representations that they expect their model to generate. The existence of prediction –whether be correct or not—helps students understand the model in depth and interpret it with a view to understanding and interpreting the phenomenon.

Organisation and connection of past knowledge - Interpretation

We noticed that modelling activities helped students link their past knowledge with the quantities of kinematics and diagrams so as to establish a better organised conceptual framework. For instance, the students linked the slope of the graphical representation with the constant of proportion and velocity in the position-time graph for a linear, constant-velocity motion, while they had not linked the constant of proportion with velocity or with slope beforehand.

Model testing

By using tests, students chose the relation they would use and how they would adjust such relation so as to model the motion described in the handout. Model testing enabled students to understand the function of the model's relations and representations.

Alternative ideas

Students do not relate equal values to the axes of diagrams with equal distances.

Misconceptions of graphical representations due to the software

The way in which the software functions may give rise to misconceptions among students. This usually happens during the first activities in the following case: simulation stops when a property gets its final value while the graphical representation continues to be plotted with values generated by the relation. For instance, students noted that the velocity increases while time remains constant. In the last versions, it seems that simulation ceases functioning because the entity changes colour when the property reaches its final value but it may be hidden by a representation.

Link of the form of graphical representation with trajectory

Sometimes, students link the trajectory with the form of the graphical representation, usually with respect to the position-time graph. In certain cases, they chose the relation so as to link the quantities of position and time from the icon given in the semi-quantitative relation. Thus, they opted for the sinusoidal function believing that they could simulate all the phases of a motion with one relation. By making tests, they realised that the simulation does not coincide with the motion they wanted to model.

Graphical representation – Control of model

The graphical representation was one of the main model control tools used by students. They focus on what interests them more, in this case in the graphical representation. They start taking notice of more points on the diagrams and the slopes on the graphical representations.

The software easily creates graphical representations within a short period of time without tiring students. Thus, the latter are offered the opportunity to reflect and express their views on issues that instructors may consider self-evident for students.

By means of graphical representations, students easily discover other information so as to supplement or modify their model.

Interaction between group and researcher

Graphical representations are an important tool for instructors because they enable them to judge whether students have structured the concepts well and how they have organised them so as to interpret real phenomena. This tool was utilised to a great extent in this research by the instructor during the design of worksheets and performance of the activities by the students.

5.5.2.4.5 Simulation

Students turn to simulation wherever something seems unusual or unknown or they have not understood it in depth and do not expect to see it. We saw students being impressed sometimes by the change brought to the simulation by the modifications made to their model. It is very difficult to impress students with traditional teaching aids. Wherever simulation is expected and they have understood it, we note that they set aside the model and focus on the model’s representations.

Wherever their prediction coincides with the simulation, they understand better the concepts and the relations for which they made predictions. There were also cases when they could not interpret the simulation of the model.

By means of simulation, activities can be designed that will stress students’ alternative ideas, such as:

- Velocity is zero at reference point.

- The values of the property being further to the left are lower.
- The sign of velocity expresses for students the following: (a) where the moving object is located in relation to the starting point. They linked the positive sign with rightward motion but examined it in a static manner, as it occurs with the position (where it is), and not with the direction (where it goes); (b) the change in velocity: «*… if you have negative velocity, this means that you decelerate*».
- Confusion between the content of velocity and the position. The velocity depends on the position of the moving object «…yes, but the fact that it moves (at a certain velocity) rightwards means that it is also a question of position».

The activities, taking advantage of the capabilities of realistic simulation offered by the modelling tool, helped students interact and contributed to a conceptual change, verbal interaction between students and to a more profound understanding of the concepts (Orfanos & Dimitracopoulou 2003).

Model testing

By means of models tests (create model & execute it), students chose the relation they would use and how they would adjust such relation so as to model the motion described in the handout. The test of the model allowed students to understand the function of the model's relations and representations.

The students made more tests with the model as they proceeded to the activities and got more familiar with the modelling tool. By means of tests, they managed to overcome and correct their initial perceptions. They also managed to overcome an alternative idea in which they confused acceleration with velocity. They had carried out many activities with velocity and had linked rather satisfactorily its sign with direction. It was shown that understanding a quantity did not suffice to help students distinguish this quantity from others for which they have alternative ideas. They should understand other quantities in depth so as to become knowledgeable about them and manage to view them as independent cognitive concepts.

5.5.2.4.6 Organised conceptual framework

Kind of motion

5.5.2.4.6.1 velocity as the Dominant concept

Students select each time the same quantity, usually velocity, so as to create the model, regardless of what the handout requires. They describe motion according to the way in which velocity changes and not pursuant to the category under which the motion falls. Here it falls under variable motions.

5.5.2.4.6.2 What kind of motion they understand

It seems that they describe and understand better the linear, constant-velocity motion. Yet, they link the concepts "increases velocity" and "it brakes" with acceleration and deceleration respectively. However, they do not describe accurately the motion and, as we will see below, they did not create models for all quantities.

5.5.2.4.6.3 Phenomenon- relation: From relation to phenomenon

Students make calculations pursuant to the formulas that they remember, as if they had to calculate the value of a quantity and not to form the relation between quantities. Students believe that there is a relation modelling the entire motion of the motorcyclist. They are accustomed to working under similar conditions so as to be satisfied with a mathematical formula that is simple and well phrased.

5.5.2.4.6.4 Description in relation to what they have been taught

The knowledge of the students is not structured. They cannot interpret or classify a motion that they meet in everyday life and does not fall under the special categories they have been taught as general groups of motions. Although they are able to recognise the kind of graphical representation, they qualify the kind of motion by using the quantity of acceleration or "change in a quantity". The other group of students, given that they do not know and have not been taught this motion, prefers answering «I don't know».

Although it seems that they understand the graphical representation, they cannot understand the relation of velocity with time. Pursuant to the goals of the learning provided at school, we expected an answer like "accelerated or changing motion". We did not get any such answer, this fact confirming our above allegation.

5.5.2.4.6.5 Formulas falling under one type of motion are used as general formulas

The formulas taught to students and used for solving exercises occupy an important position in the tool kit of students. They used the formulas of linear, constant-velocity motion without initial position, at the motion where initial position exists. They did not use the general formulas of change in position to change in time, although they had reported and written them down in the handout. The book taught at the 3rd class of high school refers solely to linear, constant-velocity motion without initial position and does not indicate that this is a special category of linear motion. It is possible that students believe that there is just this linear, constant-velocity motion and, therefore, solely the formulas mentioned in the schoolbook are applicable. Students are not assisted in understanding which formulas have an overall effect and which apply solely to special cases. So, we notice that students know the right formula but do not choose it. It is worthwhile noting that they have written such formula 10 times.

Motion during consecutive phases

5.5.2.4.6.6 How they describe the phenomenon

Students describe what impresses them, ignoring sometimes the question. Initially, they describe the phases in their own intuitive manner and not in the scientific way they have been taught at school.

5.5.2.4.6.7 How they analyse it

Students describe the real motion analysed in different phases intuitively. They realise that there are phases and that motion can be analysed. However, they believe that there is one relation modelling the entire motion. They do not describe the phases they distinguish in a scientific and rounded manner with respect to the kind of motion but with respect to the quantity dominating, in their opinion, in each phase, e.g. they describe accelerated motion as Acceleration. The number of phases analysing a motion is not the same for all quantities; for some quantities we have two phases and three for some others.

5.5.2.4.6.8 Phenomenon and reality

Students start realising that what they learn is a simplified version of reality and cannot meet each and every case but they should combine appropriately what they know so as to approach a real phenomenon. They believe that, in effect, there is only what they are taught at school or know from the books. As a result, they have an idea about reality other than the one that we try to teach them.

5.5.2.4.6.9 Function - relation

Understanding the concept of relation

Students do not use correctly the formulas. The errors noted most frequently lie in the students not knowing the correct formula, making a false replacement and not making out which formulas have a general effect and which apply solely to special cases. The formulas they have been taught in the classroom and have been used in solving exercises seem to occupy an important position in the tool kit of students. It seems that students believe they have a general validation range

Relation of one quantity with another

During the first activities, students study what occurs to one quantity and not what occurs to one quantity in relation to another. For instance, they have understood that velocity determines the change in position but do not refer to a rate of change or time in a certain way, e.g. fast or otherwise.

As activities advance, we notice that they formulate the relation of quantities in a rounded manner. They understand in greater depth the concept of relation and which quantity depends on another.

5.5.2.4.6.10 Relation Forming

Forming a relation requires understanding of both independent and dependent variable. Originally, students did not make any distinction between independent and dependent variables and in certain cases they referred to time as a quantity we could change. As activities progressed, they managed to make this distinction.

5.5.2.4.6.11 Variable - constant

The relation of the constant turned out to be one of the most difficult. It was not easy for students to understand how one variable changed and the other remained the same.

5.5.2.4.6.12 Link of quantities - Relation

Initially, students believed that the link of quantities suffices to create a relation. This, however, may occur solely in the semi-quantitative relation of two quantities. Many times, students linked the quantities without forming any equation thinking that this was enough. They believed they had established the model because they used the relation. There are typical examples showing that initially they had not understood the concept of relation:

They selected the property of the entity without linking it with any relation and believed that this takes part in the model.

As for semi-quantitative relations, they did not adjust initially the constants and wherever there were more than two variables, they did not link more than two in a relation.

As for quantitative relations, they linked variables without forming any relation. In one case, they argued that they did not have to form an equation because the quantity was constant.

Link between more than one quantity

The original models created by students do not interpret the phenomenon as a whole. Each relation expresses a part of the model. Thus, the relations between properties were independent from each other. Each relation linked one quantity with time. The activities aimed to link gradually all three quantities by way of one relation by structuring and understanding the concepts, examine more closely the meaning of the relation between them and, finally, express such relation in a quantitative manner.

Equation of the position at constant-velocity motion

The function of the model they created helped them understand the kind of motion by means of representations, initial position and the list of values, which is also used for calculations.

5.5.2.4.6.13 Identification of quantities in a quantitative relation

As regards the equation of position, students identify solely the position and time without identifying the velocity or the initial position. By way of the activities, students gradually acknowledge the role of each factor of the equation to the function of the model but do not match it with the respective physical quantity.

5.5.2.4.6.14 Identification – Understanding the role of the sign

Simulation helped students understand the role of the sign to the factor of time. By changing the value or the sign to the factor of time in the equation of position and by focussing on the simulation, students seem to understand the results and identify its role with that of velocity.

5.5.2.4.6.15 Forming of equation

Forming an equation requires more advanced thinking skills (higher school class) than the use of a formula for calculating the value of an unknown quantity. Students know the formulas but cannot form a quantitative relation. They focus on calculating the value of a quantity and not on forming the relation between quantities.

We also noted that students had difficulty in finding the kind of mathematical operation they would use so as to include the initial position in the equation. They found that the equation should be supplemented with the initial position and linked it with the act of multiplication. At this point, the graphical representation was utilised.

5.5.2.4.7 Independent – dependent variable

In order to become able to interpret scientifically phenomena of everyday life, students initially need to distinguish the cause from its effect as well as the independent from the dependent variables. In MODELLINGSPACE, the user has to distinguish the independent variable that is discerned by the type of lines. In model of Figure 1, the 'time' is the independent variable. The students' worksheets have been designed in such a way so as the students to think about the type of the variables and the relation connecting them in order to proceed-for a start-to a rough scientific organization of the concepts at issue.

Analysing the corresponding research data, we noticed that the students can not distinguish the independent from the dependent variables, especially during the initial activities. By quoting some of the students' dialogues in chronological order, we can notice the positive contribution made by the modeling activities to the deeper understanding of the dependence of the first magnitude's values on those of the second one. In the first activity the student "Giorgos" made the following question. "*Let say that time is proportional to position. Is this the same as saying that position is proportional to time?*" Next week "Giorgos" worked with another student "Tasos" who was not present in the previous activity. They were both asked to fill in some missing values in a table constructed to relate position to time and then to explain how they reasoned in order to accomplish their task. "Tasos" justified their choice saying that they opted for the specific values *"because time is proportional to position"*. After this answer, we had the following dialogue:

S232 Giorgos: *Because position is proportional to time.*
S233 Tasos: *Oh! Yes. Because time is proportional to position.*
S234 Giorgos: *Because position is proportional to time.*
S235Tasos: *Why?*
S236 Giorgos: *Because position is proportional to time.*
S237 Tasos: .. .
S238 Giorgos: *What are you saying; No one can affect time.*

It seems that "Giorgos" had understood the concept of the magnitude-dependence qualitatively and in depth. He did not recollect his answer and he used sound arguments with a view to convincing his colleague. Another characteristic example is what another student "Anne" said: "*Position is proportional to time…or time is proportional to position? Oops, what am I saying?*" Next, we noticed that her team linked the variables correctly.

5.5.2.4.8Proportion relation

We asked the students to answer questions concerning the change in the constant of the relationship of proportion like *"what can you change in the model so that the motorcyclist increases his speed?"* It is to be noted that the user of the MODELLINGSPACE can change the values of the constant. We found that, even though the students had been previously taught (during traditional lesson) what the constant of proportion is, they were still ignorant of the concept's exact meaning.

The types of confusion we noticed in a number of activities are as follows:

i. Some students answered correctly
ii. Some of them considered the proportional relation as a constant relation.
iii. Some others, when -following the worksheets- they changed the value of the constant of proportion, incorrectly, concluded that the relation between the two magnitudes was not proportional any more.

When the value of the constant of proportion relation was one, we noticed that the

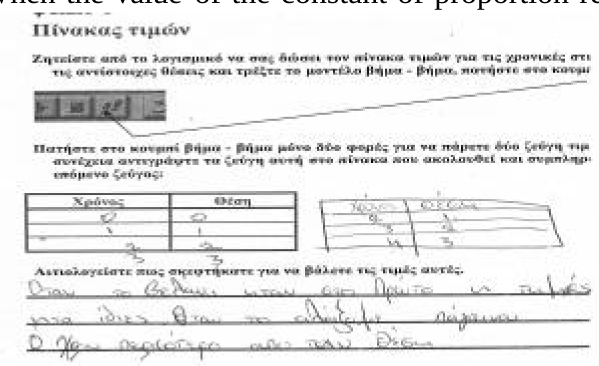


Figure 2 Right-hand table is inconsistent with proportional relation. *??????'* = Time, *T?s?'*

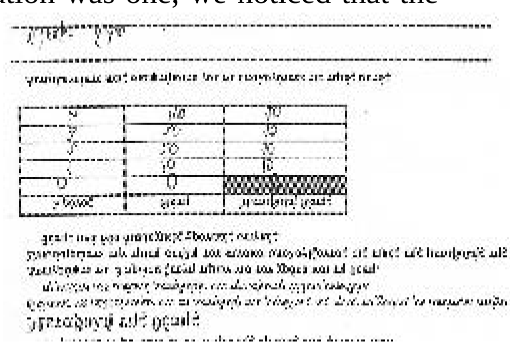


Figure 3 Proportional relation instead of constant relation. *'??????'* = Time, 'T?s?*'* =Position

students used to grasp the relation of proportion as well as its representations. In all the cases, the first indication of some confusion appeared when the constant of proportion was different from one.

The students trying to show how the value of the position changes in relation to the time filled in the left-hand table, presented in Figure 2. With their own initiative they constructed the right-hand table to bring out another case in which the constant of proportion takes a different value. We can notice that the right-hand table is inconsistent with proportional relation. One group, commenting on the change of the position-values in relation to the time-values as presented in the table in Figure 3, responded as follows: *"…it changes in proportion to the time*". Similar was the answer of another group. Some of the right answers could be that change of the position is constant or that is always ten.

During another activity, the students constructed a correct model in which the position was proportional to the time. However, when they were asked to construct another model for the same motion, in which the velocity (and not the position as in the previous one) was related to the time, one group confused the relation of proportion with the relation of constant. Another indication of underlying conceptual difficulty is the answer given on a worksheet of another group. When they were asked to change the value of the constant of proportion they answered as follows: *"If we decrease the constant the time is not proportional to the position"*. The same group when asked 'what one can conclude if one increases the constant of proportion?' responded that *"in this case both the time and the position increase*". Concerning their reasoning during modelling, we found that they used to check whether or not the relation they choose in their model was correct by comparing the graph they had predicted with that provided by their model. They found out that the relation they used was inadequate because the model's graph was not in accordance with their prediction. Most students then discovered that the constant of proportion is represented by the slope of the graph.

In most advanced activities, where the students worked with quantitative reasoning we observed that they were expressing their ideas more adequately. Trying, for example, to express the change of one magnitude in relation to the other (time), they put it as follows: *"The displacement is constant concerning the time in equal time intervals"*. This formulation shows that they grasped deeply the significance of the relation and were able to distinguish the independent from the dependent magnitude. We have also observed (from video data) that other students were impressed by the results effected by the changes in the factors of quantitative expressions, in the simulation of the running model and they often found themselves in a state of cognitive conflict.

We concluded that the possibility given by the ModellingSpace environment to change the constant of a relation, the simultaneous observation of the simulation and the construction of graphs and/or of table of values, contribute to the understanding of the relation of proportion and the interpretation of its graph. We quote some of the students' dialogues in which they justify how they made the motorcyclist run faster by increasing the constant of proportion.

S 521 Heleni: *The more the value of position increases the more the value of velocity increases too.*

S 522 Anna: *Yes, because 20 divided by 1 equals 20, it is not 10. (*10 was the velocity value in the previous case when the value of the constant of proportion was less.*)*

'Heleni' grasped the relation of the position to the velocity and came to realize that increasing the velocity affects the relation of the position to time. 'Anna' calculated the value of the velocity (20) from the new values in the table provided by MODELLINGSPACE and compared it with the previous one (10).

5.5.2.4.9Constant function

Students at this age and even older ones, as established by pilot research, have difficulty in understanding the constant function. As for semi-quantitative relations, they used the relation of the constant without any problem, this showing that they understand the constant relation between quantities. When they had to form the quantitative relation, however, it was shown that their problem did not lie solely in such forming. Their dialogues suggested that they had not understood what constant function means or that the value of the variable is constant while the value of time changes continuously. Students see only one of the two quantities. It became evident that they have difficulty in understanding the simultaneous evolution of both quantities and, all the more, when one quantity maintains the same value.

During the pilot research, we noticed that initially they tried to write «velocity = constant».

The first answer we got from students and from pilot research is that wherever the quantity is constant its value is equal to zero. The researcher continued and asked which other value was constant. Students answered «one» and «zero». The researcher asked them again and students gave as answer what they had understood in lieu of the constant function: «Since time changes, the velocity will change; it will not remain the same».

Many times they used the concept of proportion instead of constant function.

Some students believed that the velocity did not play any role in the model because it remained constant. Students understand the concept of constant in a different way from physicists- experts. We noticed that wherever they thought the value of a quantity was constant they did not find it necessary to indicate this in the equation editor –although they linked it in the relation—arguing that it is constant.

During the subsequent activities and owning to interaction with the instructor, students realised how they should form a relation about the constant function by giving a constant value associated with reality, e.g. the velocity is 20 kilometres per hour.

5.5.2.4.10 Group 6

5.5.2.4.10.1 Question 1

Choose the property of velocity by using the quantitative relation F(x)=?. Form a relation expressing the velocity of the motorcyclist as well.

George: *Now, how will we link them? How will we make velocity constant? How will we link it with time in this equation?*

In the quantitative relation, they have linked velocity with time.

Comment 5.14

It seems they have understood to an extent the concept of constant function. They understand that velocity is a dependent variable and that time is the independent variable.

George: *It does not turn out.*

Alecos: *Yes, it does.*

Researcher: *Look….relation*

George: *Let's put another relation*

Researcher: *Why don't you make it constant?*

George: *There is no constant… with this relation.*

Comment 5.15

It was easier to form the semi-quantitative relation. Such forming means that they have understood in depth the concept of function. The dialogue with the students stressed their alternative ideas about the constant function.

Researcher: *Press on the dots to correct it.*

He describes the procedure of forming a quantitative relation.

George: *But it can't be corrected, no matter what we put.*

Students state that they have tried and the researcher realises that they know how to use the editor of equations. Therefore, it is the function they do not understand. So an exploratory dialogue starts.

Researcher: *What does constant mean?*

George: *To remain constant and not change*

Researcher: *So, what's the value?*

George: *Zero.*

Comment 5.16

The alternative idea of one student came to light and was also articulated by the other student of the group. We had also noticed this alternative idea during pilot researchers. Constant is identified with zero.

Researcher: *What else?*

George: *one… since time changes*

Alecos: *zero*

Researcher: *Is only zero constant?*

George: *Zero is the unique constant point.*

Researcher: *What else is constant?*

The researcher asks them to seriously reflect on this point because it is important.

George: *once time changes.*

Researcher: *.. So, how are we going to form the equation?*

George: *Once time changes, the velocity will change too, it will not remain constant.*

Researcher: *You will have to form the equation so as not to affect the velocity.*

He shows them how to modify the equation in the editor.

George: *The whole equation must change.*

He said so in a way implying that it would be very difficult and time-consuming to change the equation. It was not difficult to form the equation but to understand the concept of the constant function in greater depth. The students were already familiar with the equation editor including the special way in which variables are indicated.

Researcher: *To what does velocity equal?*

Alecos: *Velocity equals…*

Researcher: *To remain constant*

George: *50*

He might have remembered the answer given to his question at the beginning of the activity. He had asked what it meant that it moved with a velocity being equal to the speed limit and the researcher had given them an example with the speed limit being 50 and then 100 kilometres per hour.

Alecos: *Could we write this here =50?*

They write it in the equation editor.

Comment 5.17

It seems that they understood the concept of constant function. The other student promptly agreed with the answer of constant value being equal to 50 and wanted to write it down immediately. The answer was the product of thought and not just learning by heart.

George: *Ah! Now it's done*

Researcher: *So, run the programme.*

George: *It doesn't change now.*

They see the simulation: time runs and the picture of the motorcyclist remains the same.

Alecos activates the equation editor, probably in order to modify the equation. George stops him.

George *No, we're right.*

Researcher: *Why are you correct?*

George: *Because it remains constant.*

Both express their relief.

Alecos: *What should I write here?*

George: *Velocity, no, not the velocity, the position is proportionate to time.*

That's how they have written it in the handout. In other words, they have deleted the word "velocity" and have written "position".

Alecos: *That's the same with the previous one*

Costas: *That's OK. Write it again.*

It's one of the few times that this student spoke. He started feeling more confident and participated more actively.

Alecos: *Should we write that the velocity changes or that it is constant?*

George: *Constant.*

He says it quietly while dealing with the model. This is why they have not written it in the handout.

They make a model solely with the position and time.

Alecos: *Let's add velocity now.*

Alecos: *Let's add velocity equal to 50*

They link position with time in the equation editor and also write 50 without, however, writing the symbol of multiplication.

Costas: *He wrote 50 there*

George: *That's wrong.*

The equation editor showed an error message because the symbol of the mathematical operation was missing.

George: *How will the graphical representation turn out? Let's do it up here.*

They have drawn a rough graphical representation on the handout, which is shown in figure 5.3.

Costas: *Good*

They comment on the rough diagram they did on the handout.

George: *Why is that?*

They ask from the software the graphical representation for the model.

George: *Here it is. See how nice it turned out.*

Costas: *It's wrong.*

George: *No, it's correct. Come on.*

Costas: *Yours has an upward slope.*

Comment 5.18

> They start noticing more things on the diagrams as well as the slopes in the graphical representations.

He reads the following question.

George: *run the model….*

They write in the handout that they have "hit it".

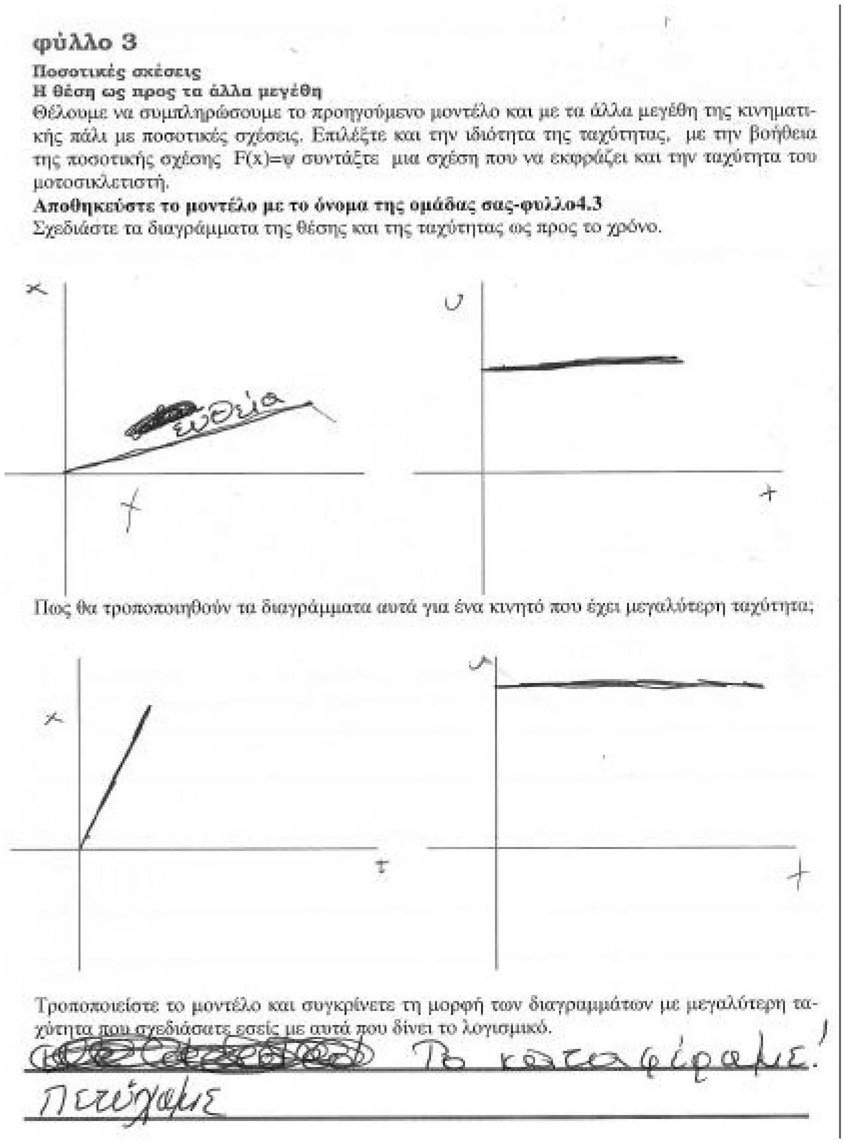
George: *It's a straight line. That's what we should write and make it certain.*

Indeed, they have written the word "straight line" on the line that is drawn on the handout and crosses the starting point. They did not have any ruler and the line they had drawn was not a perfect straight line. That's why they indicated it (figure 5.5).

They create a model. They link the position with time and add the velocity as parameter so as to write it subsequently in the equation. It is a good step so as to link all three quantities.

They activate the equation editor and form one equation including solely the position and time. The relation does not include the velocity although it has been linked (figure 5.6).

Researcher: *So, you have made a relation. What have you written? The position of the motorcycle equals…?*


φύλλο 3

Ποσοτικές σχέσεις

Η θέση ως προς τα άλλα μεγέθη

Θέλουμε να συμπληρώσουμε το προηγούμενο μοντέλο και με τα άλλα μεγέθη της κινηματικής πάλι με ποσοτικές σχέσεις. Επιλέξτε και την ιδιότητα της ταχύτητας, με την βοήθεια της ποσοτικής σχέσης F(x)=ψ συντάξτε μια σχέση που να εκφράζει και την ταχύτητα του μοτοσικλετιστή.

Αποθηκεύστε το μοντέλο με το όνομα της ομάδας σας-φυλλο4.3

Σχεδιάστε τα διαγράμματα της θέσης και της ταχύτητας ως προς το χρόνο.

Πως θα τροποποιηθούν τα διαγράμματα αυτά για ένα κινητό που έχει μεγαλύτερη ταχύτητα;

Τροποποιείστε το μοντέλο και συγκρίνετε τη μορφή των διαγραμμάτων με μεγαλύτερη ταχύτητα που σχεδιάσατε εσείς με αυτά που δίνει το λογισμικό.

Το καταφέραμε!
Πετύχαμε

Figure 5.5

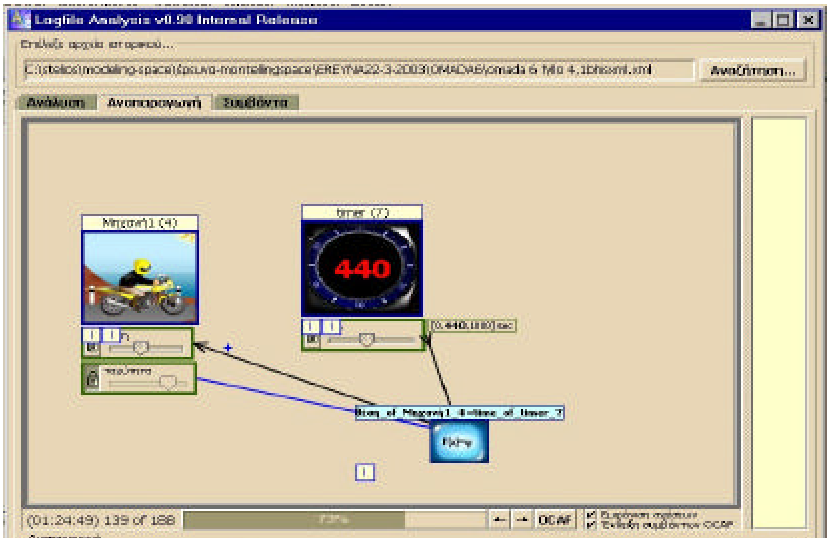


Figure 5.6

George: *He asks the time? Doesn't he tell us?*

Researcher: *Is velocity included?*

George: *The velocity is constant.*

Researcher: *Does the position depend on velocity?*

Comment 5.19

While the first step was made and they linked the velocity with the relation, they have difficulty in realising that it should be also included in the equation.

George: *Suppose we make it higher…*

He changes the value of velocity.

Researcher: *Go ahead. Does the diagram change?*

They make the diagram.

Researcher: *Run it with one value of velocity and then with another.*

He tries it with one value of velocity and the position-time graph is plotted.

Researcher: *Change the velocity*

He changes the velocity and runs it again.

George: *Yes*

Researcher: *Does it look the same? Velocity doesn't seem to change. Because in the relation of position…*

Researcher: *Take a look. Is there any velocity in the relation of position?*

George: *It's here.*

He shows the line linking the velocity, but he doesn't activate the relation.

Researcher: *You have no velocity in the relation.*

Then they activate the equation editor.

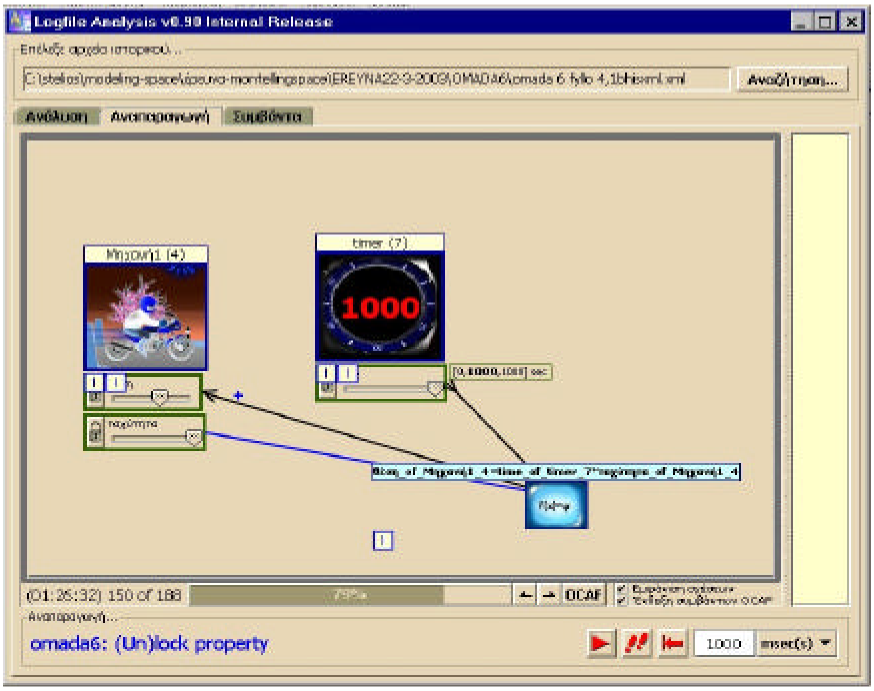


Figure 5.7

George: *Where? Right here?*

He shows the equation of relation.

Researcher: *Does it exist?*

George: *No*

Researcher: *So, how are you going to understand that position is linked with velocity and time?*

George: *Multiplied by*

Researcher: *By?*

They supplement the equation in the editor by adding velocity, as shown in figure 5.7.

Comment 5.20

They linked the velocity but did not find it necessary to include it in the equation. They argued that it is constant.

By way of tests, the students realised that the velocity does not play any role in the model. So, by using their model as scaffolding, they were led to include it in the equation.

George: *What?*

He asks for confirmation. The researcher proposes them to try it.

Costas: *Only the two of us work.*

His comment refers to the third student of the group, Alecos, who does not participate in the activity.

They make the position-time graph, which turns out to have a negative slope.

George: (*with an exclamation*) *it turned out.*

He changes the value of velocity and runs it again.

George:*(with a louder exclamation). Ah! It depends, it depends. We did it.*

Now, it comes out with a positive slope and they celebrate.

Comment 5.21

> They understand that given the velocity is negative, the slope is negative too in the position-time graph. So, they immediately change the velocity so as to obtain a positive value. They test the model and get the results they expected to their satisfaction.

Alecos reads further on. It is worthwhile noting that as long as they did not get any results, Alecos had stopped participating in the activity and had focussed on the camera. His fellow students had also remarked that it was only them who worked. But, as soon as they got some results, Alecos showed an interest again in the activity.

Alecos: *Modify the model and compare the form of the diagrams with higher velocity that you have drawn with those generated by the software.*

Alecos: *What am I supposed to write when it says "Modify"?*

George: *We did it.*

Alecos: *We did it.*

It seems that the group is filled with enthusiasm.

George: *It moves in the opposite direction.*

They apply a negative value to velocity. Thus, the motorcyclist changes direction. They have written in the handout that they take notice of the simulation but they did not do it after the question. They may refer to what they initially saw and said subsequently that it turned out.

He thinks about the question asking them to modify the model so as to move in the opposite direction. Using the cursor, he changes the value of velocity so that it becomes negative. They notice in the simulation that the motorcyclist changes direction and faces leftwards.

Comment 5.22

> They also have the model here. They have focussed on the direction of motion because simulation shows some things. During previous phases they had the diagram on the model.

5.5.2.4.11 Alternative 'scientific' ideas: Conceptions and misconceptions related to kinematics concepts

The following alternative students' ideas has emerged during learning activities with MS

Alternative ideas referred to the related bibliography of Science Education

1. Students confuse moment with time period
2. They confuse the change of position with velocity
3. They confuse the content of the concept of velocity with acceleration while when they discuss about acceleration they say that it first moves fast and then moves more slowly.

Alternative ideas not mentionned in bibliography

4. Students believe that at zero moment velocity is zero too, although there is motion with constant velocity.
5. There is the concept of constant quantity that students do not fully understand, as shown.
6. They link constant quantity with zero value.
7. They seem to prefer the quantity they will use so as to determine the kind of motion.
8. Students have misunderstood the phrase "consecutive values in pairs". They took it as one value and as the next but one.

5.5.2.4.12 Contribution to the understanding of quantities – relations – formulas – laws – everyday language

Students are offered the opportunity to reflect and express their viewpoints on fundamental issues that are frequently believed self-evident and self-explained. It is possible that the instructors themselves find them self-evident. Even students discover what they have not understood.

They recognise more easily whether they have selected an inappropriate relation but they have greater difficulty in understanding which concepts are linked erroneously.

They realise that the quantities are inter-related and that the relation of one quantity with time enables them to find the other quantity, even if this is not indicated in the relation.

At first place, students understood the quantities and, subsequently, linked or identified them, for instance the proportion constant with velocity in the EEC.

They also understood that there are motions other than those they have been taught.

They understood the relation of two quantities; while initially they expressed the change of one quantity they further expressed the relation of the quantity with time.

They still remember what they have learnt from past activities even after a long period of time.

During the traditional lessons, students are solving problems, which usually require the use of algebraic relations. Problems of this kind were also solved by students who participated in the present research. We noticed that certain self-evident topics like the simple relations of proportion, which –likely- is the easiest to grasp, have not been comprehended by the students. It is not uncommon to find students who are able to solve problems by using complicated relations without getting a qualitative and in-depth grip on them. Researchers have already shown that students often have a formal mathematical and physical knowledge without a qualitative understanding of basic concepts and relations" [6]; [9];[11].

Concepts not yet understood by the students, and inappropriate mental representations are especially difficult to trace and students cannot manifest them, unless they are invited to deal with situations that require high order thinking. Situations of this kind appear more often in modelling activities than in traditional education. The modelling activities that utilize the full potential of an appropriate technology based learning environment with multiple representations contribute positively towards construction of the scientific concepts and discovering of their relations among them, while support the students who previously had only a feeble grip on them, achieve an in-depth understanding.

The student deal with complex situations, do not have to do routine work, like numerical calculations, or to manufacture many graphs. These assignments get them tired, distract them with trivia and deter high order thinking. With the aid of modelling activities the students are able to approach more complex situations, to really think in terms of scientific variables, to understand the transformations of the situation under study into relational terms [11], to choose the most appropriate representation/s on screen, and thus to solve more complex problems. Technology based modeling environments could be used during guided discovery activities (guided by well educated teachers), for conceptual construction and change, even before working on complex modeling processes.

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6 TEACHING & LEARNING DURING SYNCHRONOUS COLLABORATIVE: MODELLING THROUGH MODELLINGSPACE AMONG CO-LOCATED STUDENT

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6.1 A. SUMMARY

The theme

This part of the report, presents the main results of the pedagogical validation research, concerning synchronous collaborative modelling activities among students, which are implemented by the University of Aegean, in three schools of Rhodes Island.

Conditions

The participants

In the research, four classes of students were participated from three public schools. Students' ages vary among K9, K10 and K12 grades. Students have in general no experience of participation in research project learning activities and/or of special educational software use.

Four teachers were participated in the learning activities implementation. Teachers did not have experience in research projects participation while they do not use special educational software for their teaching.

The technological infrastructure and experience

The schools offered their computer rooms for the project needs. In these rooms there are usually about 12 multimedia pcs connected through a 100Mbps LAN and an ISDN dialup internet connection of 64Kbps.

The modes of use

Three modes of use are systematically examined under realistic school conditions in order to evaluate the pedagogical value and applicability of ModellingSpace. The modes of use concern students collaborating using pcs connected to the LAN of the school computer room. The difference between the modes of use is the participation or not of a teacher in the collaboration and the number of students in front of each pc. The modes of use are described in detail in the followings.

The content of learning

For the needs of the study a special series of learning activities has been designed with central theme the general system y=ax+b.

The available time

Students had 8 sessions of 45 minutes (maximum) available for the full set of learning activities implementation.

The integration

For two groups of the students the activities have been integrated in their usual schedule while for the rest two special after normal school hours has been decided.

The data collection tools

Plenty of research data have been collected from the log files of ModellingSpace, to the activity sheets of students, video & audio recordings of collaborations, students & teacher questionnaires, panel videos etc.

The main questions

The corresponding data of the four case studies were analysed regarding to the following issues:

- The tools that support teachers for collaborative learning activities implementation and management during (online) and after (offline) the collaboration sessions.
- The meaning, the quality, and the strategies of synchronous collaborative problem solving through MS for the specific modes of use.
- The comparison of the modes of use.
- The motivation of students to work on collaborative modelling activities
- The students and teachers point of view for the learning value of collocated collaborative problem solving using MS.
- The study of teachers' interventions and their consequences when they participate/supervise or guide the synchronous collaboration between two students.
- Students' ideas about models and modelling after ModellingSpace use.

In the followings some information about the schools and the participants are summarized first in section B, the learning activities are briefly presented in section C, the context and conditions details of the study are described in section D, the participants population data are stored in section E, then the data collection tools are briefly described in section F, the main research results are presented in the extended section G and finally the conclusions are concentrated in section H.

6.2 INFORMATION RELATING TO SCHOOLS AND TEACHERS IMPLIED IN MODELLINGSPACE PROJECT

6.2.1 Information related to schools

School Names	Schools	ClassGroup	Number of pupils	Teachers' name	Disciplines taught
2nd TEE of Rhodes	*Secondary*	*TGP (K12)*	22	Anastassios SAVAS	Computer Science
		TAP (K10)	25	Demetrios KLADOGENIS	Computer Science
3rd Gymnasium of Rhodes	*Secondary*	*3G (K9)*	8	Elisabeth MAVROUDIS	Computer Science
5th Gymnasium of Rhodes	*Secondary*	*5G (K9)*	7	Christos MITSOULLIS	Mathematics

Table 1. Information about the students' groups of the study

SCHOOL	COMPUTER ROOMS	PCS PER PUPILS	POWER	YEAR	CD-ROM / SOUND CARD	INTERNET
2nd TEE of Rhodes	3	36/640	PIV 1.7 GHz	2002	YES	1 Mbps Dedicated Line
3rd Gymnasium of Rhodes	1	8/450	CELERON 700 MHz	2000	YES	64 Kbps Dial up
5th Gymnasium of Rhodes	1	12/275	PIV 1.7 GHz	2002	YES	64 Kbps Dial up

Table 2. Some details for the ICT infrastructure of the schools

In Greek Education system there is independent subjects in which students study some general principles about information and telecommunication technologies, programming etc while they learn to use basic productivity software tools and the Internet. The subject is distributed in several grades from K3 to K12; it is for 1 hour/week for K7-K9 and 2 hours/week from K3 to K6 and K10 to K12. Especially, the 2nd TEE is a vocational school and the pupils participated the research attend the informatics discipline. These students study a wide range of ICT subjects like operating systems, hardware installation and maintenance, web programming, data bases etc from K10 to K12. Students of 2nd TEE spent about 20 hours/week in the laboratories.

There is not officially obligation for other disciplines to teach using ICT but teachers are encouraged to exploit ICT's in the educational process.

6.2.2 Information related to teachers

Four teachers were participated in the learning activities implementation. Teachers did not have experience in research projects participation while they do not use special educational software for their teaching. Teachers Elisabeth MAVROUDI, Anastasios SAVAS, and Demetrios KLADOGENIS are computer scientists while

Christos MITSOULLIS is Mathematician. Mrs MAVROUDI selected a group of volunteers students from different classes and worked in after school schedule. Mr MITSOULLIS worked also in after school hours but with a group of his students. Mr SAVVAS and Mr KLADOGENIS worked in their normal schedule intergrading the ModellingSpace in their lessons about programming and computer networks respectively.

6.3 Learning Activities

For the study needs, a sequence of four activities around a basic family of systems expressed by the relation y=ax+b have been designed. There are several physical systems that can be described using the y=ax+b relation from different disciplines. The main intention was to see if it is possible to use MS to implement conceptual experiments using specific problems in order to generalize the underline system structure and dynamics. More specifically after quick familiarization with MS student's created two similar models in order two solve corresponding problems of everyday life. In the last activity students exploit MS in order to implement systematic conceptual experiments producing graphs changing the parameters (a, b) of the abstract relation y=ax+b and a typical understanding assessment test in order to evaluate the learning outcome of the activity sequence. In other words students represented with MS several specific systems of the form y=ax+b in order to develop a deep understanding of it and increase the possibilities of interdisciplinary knowledge transfer. Using this systemic point of view for the design of the activities the following main research question axes has been defined:

Models and Modelling

What are the students know and believe about models and the modelling process before and after the activities implementation with MS?

What makes a model valid for students?

How do students understand the execution-simulation of an MS model?

Collaboration

Are students able to get involved efficiently in collaborative projects using MS? What is the quality of collaboration according to the mode of use? Is MS neutral of aspects like instruction management and teaching and learning styles? Can MS be used as mirror for the awareness of these aspects from the participants? Can we describe general pattern of participation of students and/or teachers and evaluate their learning consequences?

Problem Solving

Do students have opportunities to develop problem solving skills using MS? For example are students integrating MS cognitive tools in their problem solving strategies?

Self regulation

Do students review their models in order to fix errors and refine their corresponding cognitive schemata? Do students engage in social negotiation about the content? Do students regulating their knowledge during these negotiations?

6.3.1 Activity 1.

FAMILIARIZATION ACTIVITY. IRRIGATING THE HORSES.

- Questions or assumptions related to the activity content and conception:
    - Students get quickly familiarized with the MS environment as well as with the basics of representation system and modelling process assumed in the MS framework.
    - The familiarization is possible using guided scaffolding learning activities based on meaningful problems in which students actively construct models and reflect on them following directions.
- Activity conceived by: *FESAKIS George, PETROU Argiro*
- Description :

The problem: *In the garden there is a barrel with water for the horses. Frequently you are refilling the barrel using a tap. The barrel can host 34000 cm^3 (34 lt) of water. The tap can give up to 100 cm^3 per second. In a specific case you find the barrel full up to the half of its height and in order to refill it you turn on the tap to the end. In order to do something else in the meantime you would like to estimate the available time you have before the water run out the barrel.*

The first activity is a mathematical problem concerning an application of the relation y=ax+b. Students are guided to produce the model in the MS with detailed directions. In the first activity the goal is to familiarise students with the MS software environment and to give basic conceptual knowledge about the models and modelling.

The students are asked to solve the problem using paper and pencil first and then they construct the model following the directions and the written explanations written in the activity sheet. After the model construction and execution, students asked to answer the following questions.

1. *How long it takes to full a half empty barrel opening the tap completely?*
2. *What position you should set the tap switch in order to duplicate the available time?*
3. *How long it takes to full an empty barrel opening the tap completely? How long with the tap ½ open and how long if tap is ¼ open? Produce the diagram showing all the cases.*
4. *Answer the question 3 for the case where the barrel is initially 10% full.*

6.3.2 Activity 2. MOBILE PHONE CALL COST.

- Questions or assumptions related to the activity content and conception:
  - How students conceive the notions of in depended and depended variables?
  - How students construct the mathematical relationships among the entities?
  - Can students apply the model they learn in the first activity in a new similar problem?
  - Can students use the MS representation tools to answer questions for the problem without the guided scaffolding of the first activity?
- Activity conceived by: *FESAKIS George, PETROU Argiro*
- Description :

The problem: *A friend asks your help in order to compute how much is going to pay for the monthly use of his new mobile phone. The phone company prises the monthly use using a standard amount plus an amount proportional to the total call time. The standard amount is 13E per month while each call second costs 0.03E. In order to help your friend you construct a model in MS for the forecasting of the cost.*

During the second activity students collaborate online in order to decide what are the data and the requested quantities of the problem as well as for the formulation of the relationship between the entities. After the model construction students asked to answer the following questions:

1. *How much is going your friend to pay at the end of the month if he spoke for 1 hour on the phone;*
2. *How many seconds can your friend speak in order to pay no more than 20 E for a month;*

6.3.3 Activity 3.

COMPARING THE PRICING POLICIES OF PHONE COMPANIES.

- Questions or assumptions related to the activity content and conception:
  - Is the knowledge of the previous activities stable in the students cognitive system;
  - Can students use two similar models in order to compare the corresponding systems behaviour;
  - Can students exploit MS in order to answer questions requiring high order thinking;
- Activity conceived by: *FESAKIS George, PETROU Argiro*

- Description :

The problem: *In the previous problem you have study a phone company prising using a standard amount of 13E per month and a cost per second of 0.03E. In a newspaper you find a commercial of a second phone company prising with 16E per month and 0.02 E per second. Use MS in order to decide which company is preferable economically and when.*

Students are asked to answer the following questions:

1. How long must someone speak in a month in order for the first company to be preferable economically?

2. When the two companied cost the same? How can we see this in the diagram?

3. If your friend speak for about 15 minutes per month which company you advice him to choose? How much money does he lose or gain now per month?

6.3.4 Activity 4.

THE RELATION Y=AX+B

- Questions or assumptions related to the activity content and conception:
    - Students can understand better the graph representations of algebraic relations using conceptual experiments in MS.
    - After a series of context sensitive activities we remove the scaffold to see the knowledge construction that was obtained.
- Activity conceived by: *FESAKIS George, PETROU Argiro*
- Description :

In this activity we study the relation y=ax+b. Our goal is to understand the role of the parameters a and b in the graph of the relation.

Students are asked then to take a short pretest about their current understanding of the relationship parameters. Then students execute a systematic sequence of graph construction for several values of a and b and after that they are constructing collaboratively a concept map about the role of the parameters in the relation y=ax+b.

6.4 CONTEXT OF STUDY

In the framework of the study in Rhodes a series of activity implementations have been realised as the Table 3 shows.

The duration available for each implementation was 2x45 minutes maximum.

The activities were implemented in the computer room of each school and several modes of use (settings) were set in parallel **(Figure 1)**.

More specifically the modes of use are:

MoU 1. OME: A group of two students and one teacher collaborating using three pcs.

MoU 2. OXE: A group of two students without the presence of any adult collaborating using two pcs.

MoU 3. OMR: Four students collaborating using two pcs. In front of each pc two students are sitting along with a researcher.

For groups AP and GP the activities were integrated in the usual schedule of the classes while for the groups 5G and 3G there where special sessions for ModellingSpace use. In AP and GP meetings all the students of the class participated.

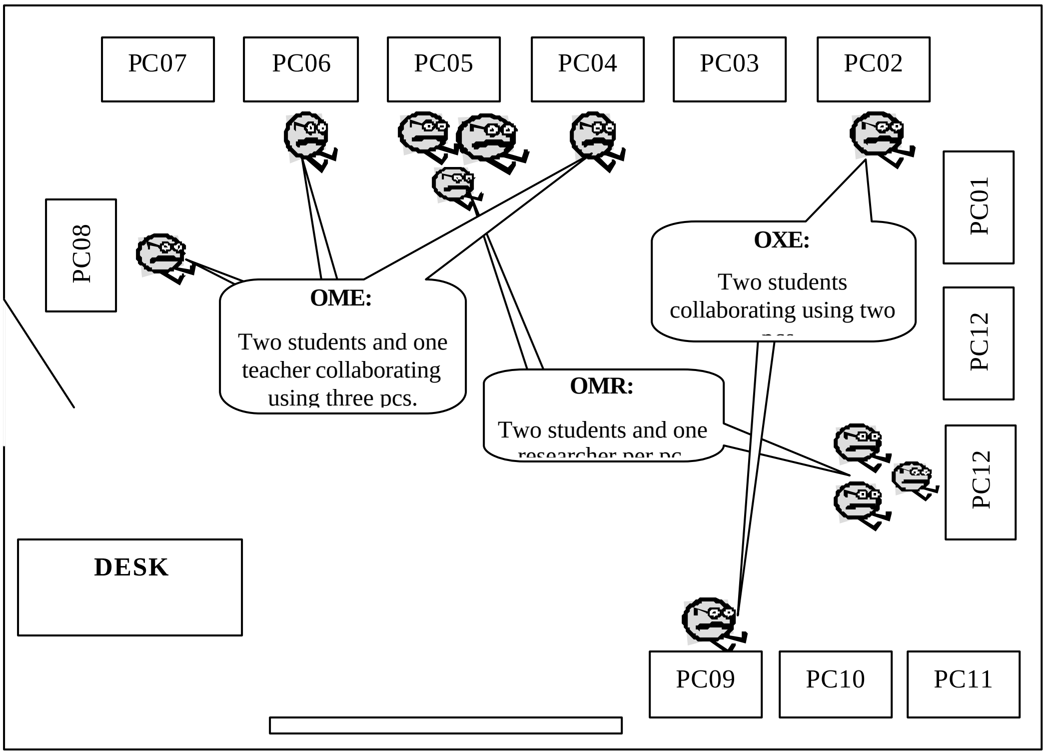


Figure 1. Modes of use illustration.

- Role of the teacher: Teachers where given general guidelines in order to facilitate collaboration, leave the students to manage their learning activity and experience social negotiations. The role of the teacher in the OME mode of use is presented in detail in a separate section below.

- Role of researcher: The researchers in OMR mode of use where basically observing the students collaborating and they had to help them in case of technical problems. They were also responsible for the research data collection equipment (video and audio recorders).

The following table is a kind of diary for the activities implementation. In the table is possible to see the number of activities implemented for each group as well as the number of students per mode of use.

					STUDENTS PER MODE OF USE			
NO	DATE	GROUP	ACTIVITY	TEACHER	OME	OXE	OMR	REST
1	24-11-03	GP	Act. 1	SAVVAS	2	2	0	18
2	28-11-03	AP	Act. 1	KLADOGENIS	2	2	4	17
3	1-12-03	GP	Act. 2	SAVVAS	2	2	2	16
4	9-12-03	3G	Act. 1	MAVROUDI	3	2	5	0
5	10-12-03	3G	Act. 2	MAVROUDI	2	2	2	0
6	11-12-03	3G	Act. 3	MAVROUDI	2	2	4	0
7	12-12-03	AP	Act. 2	KLADOGENIS	4	2	4	15
8	15-12-03	GP	Act. 3	SAVVAS	2	2	2	16
9	17-12-03	3G	Act. 4	MAVROUDI	2	2	4	0
10	19-12-03	AP	Act. 3	KLADOGENIS	3	2	0	17
11	15-1-04	5G	Act. 1	MITSOULLIS	2	2	4	0
12	17-1-04	5G	Act. 2	MITSOULLIS	2	2	4	0
13	19-1-04	5G	Act. 3	MITSOULLIS	2	2	2	0
14	21-1-04	5G	Act. 4	MITSOULLIS	3	2	2	0

Table 3. The diary of the activities implementation.

6.5 POPULATION

The participants in the research are in the following table.

NO	SURNAME	NAME	ROLE	SCHOOL-GROUP
•	Giannakopoulou	Dimitra	RESEARCHER	U.o.Aegean
•	Kladogenis	Dimitris	TEACHER	2nd TEE of Rhodes
•	Mavroudi	Elisabeth	TEACHER	3th Gymnasium of Rhodes
•	Mitsoullis	Christos	TEACHER	5th Gymnasium of Rhodes
•	Petrou	Argiro	RESEARCHER	U.o.Aegean
•	Savvas	Tassos	TEACHER	2nd TEE of Rhodes
•	Tzanetopoulou	Katerina	RESEARCHER	U.o.Aegean
•	Fesakis	Giorgos	RESEARCHER	U.o.Aegean
•	Vedni	Robert	STUDENT	GP (K12)
•	Kampassis	Christos	STUDENT	GP
•	Kinnas	Michalis	STUDENT	GP
•	Liakata	Eleni	STUDENT	GP
•	Roussou	Viki	STUDENT	GP
•	Xatzixristodoulos	Nikos	STUDENT	GP
•	Christopoulou	Sofia	STUDENT	GP
•	Alta	Maria	STUDENT	AP (K10)
•	Antimisiaris	Costas	STUDENT	AP
•	Dirmillis	Giener	STUDENT	AP
•	Emiralli	Ogia	STUDENT	AP
•	Zachariadi	Natasa	STUDENT	AP
•	Kanakis	Nikos	STUDENT	AP
•	Karipi	Athina	STUDENT	AP
•	Katsouraki	Kaliopi	STUDENT	AP
•	Kornaropoulos	Giorgos	STUDENT	AP
•	Aroni	Tsampika	STUDENT	3G (K09)
•	Giakoumaki	Frosoula	STUDENT	3G
•	Zelixovski	Igkor	STUDENT	3G
•	Tharenou	Panagiota	STUDENT	3G
•	Kolokitha	Alexandra	STUDENT	3G
•	Pavli	Anna-Maria	STUDENT	3G
•	Rossos	Christos	STUDENT	3G
•	Chaska	Alkmini	STUDENT	3G
•	Antoniou	Maria	STUDENT	5G (K09)

•	Aygoustis	Kiriakos	STUDENT	5G
•	Vakondiou	Aggeliki	STUDENT	5G
•	Daouti	Constantina	STUDENT	5G
•	Demenaga	Anna	STUDENT	5G
•	Dimitrouli	Rodoula	STUDENT	5G
•	Zoi	Eleni	STUDENT	5G
•	Katsikaki	Anastasia	STUDENT	5G
•	Kiourdis	Michalis	STUDENT	5G

Table 4. Table of the participants

Students participated voluntary. In cases of 5G and 3G groups the activities were implemented in after school hours while in case of GP and AP the activities were intergraded to their usual schedule. Students of GP and AP groups are considered more familiarized to ICT technology since they are in vocational school studying information technology.

6.6 COLLECT OF DATA

For the approximation of the research questions a large collection of data has been formulated using the following data collection tools.

Data collection tools for each activity

1. Log file

ModellingSpace creates automatically a log file containing details about every action of the collaborating agents. Using this log file it is possible to reproduce the whole collaboration session. Many of the analyses that will follow are based on the log files of the activities implemented.

2. Activity sheets

The activity sheet that students and teachers used is another data source. Students asked to note the answers of the questions on the activity sheets.

3. Video and audio recorders for OMR

The conversation of students participated in OMR groups was recorded in audio tape. In addition a video camera was set up for each group in order to have also students' gestures.

4. Video and audio recordings of conversations with teachers after each activity about the evaluation of collaboration analysis data.

Other data collection tools

1. Questionnaires before the activity start and after their completion

There are separate questionnaires for students and teachers. The questionnaires for teachers concern the collaborative learning and ModellingSpace assessment while those for students concern in addition the analysis of their ideas about models and modelling.

2. Panel video from students of 3G

After the completion of the activities in 3G a panel with all the participants was recorded.

6.7 DATA ANALYSIS

6.7.1 G.I. Interaction Analysis Tools supporting Collaborative settings

a. Introduction

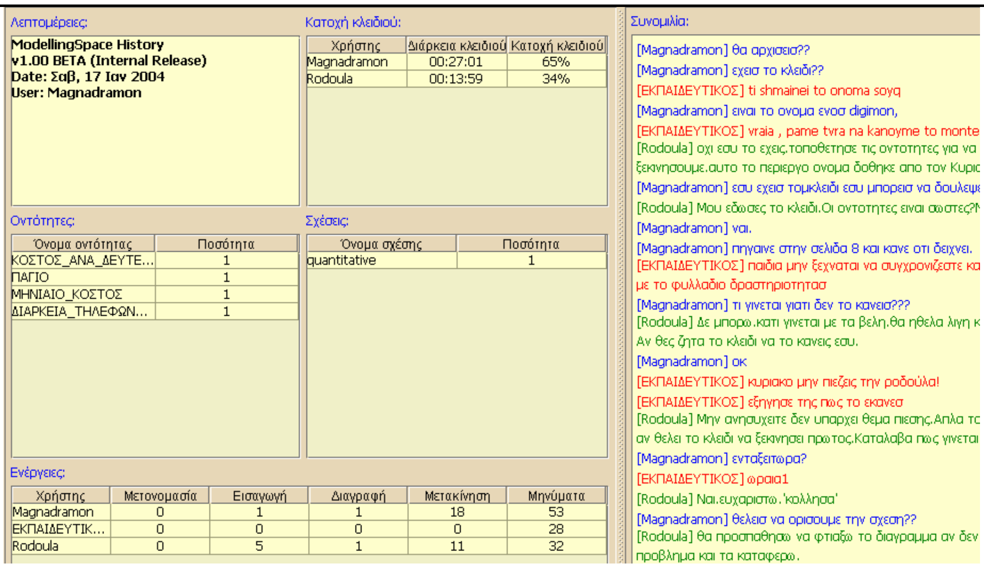
Collaboration is the co-construction of knowledge with the mutual engagement of participants (Liponnen, 2002). Computer supported collaborative learning is focused on the enhancement of peer interaction, groups' working, and the facilitation of knowledge sharing and distribution (Liponnen, 2002). Consequently, collaborative learning environments should analyze collaboration and provide this information to participants in order to really support them. This includes both the content level and the interaction/collaboration level.

Some collaboration analysis' methods process the collaborative discussions or dialogues facing natural language understanding problems (Baker & Lund, 1996), (Barros & Verdejo, 1999). In (Constantino-Gonzalez, Suthers & Icaza, 2001) a heterogeneous approach is described, in which dialogue input along with state information is used for the analysis of collaborative modeling. Finally, in (Muhlenbrock, 2001) direct manipulation user actions have been used as input material in combination with plan recognition techniques.

As far as the limitations of the above analysis method are concerned, the linguistic analyses are of different nature, and depending on a classification of dialogue acts, which is not fully automatic (Gaßner, Jansen, Harrer, Herrmann & Hoppe, 2003). In addition, plan recognition techniques cannot be applied to all domains and are not so usable. Besides, we are interested in teacher's role during synchronous collaborative problem-solving, where the teacher observes students' interaction in real-time and intervenes in order to help them. Teachers need tools, which provide them with the possibility to attend many groups at the same time and estimate quickly the evolution of the collaboration.

b. Short presentation of tools

ModellingSpace has the interaction analysis tools that are presented at the following table.

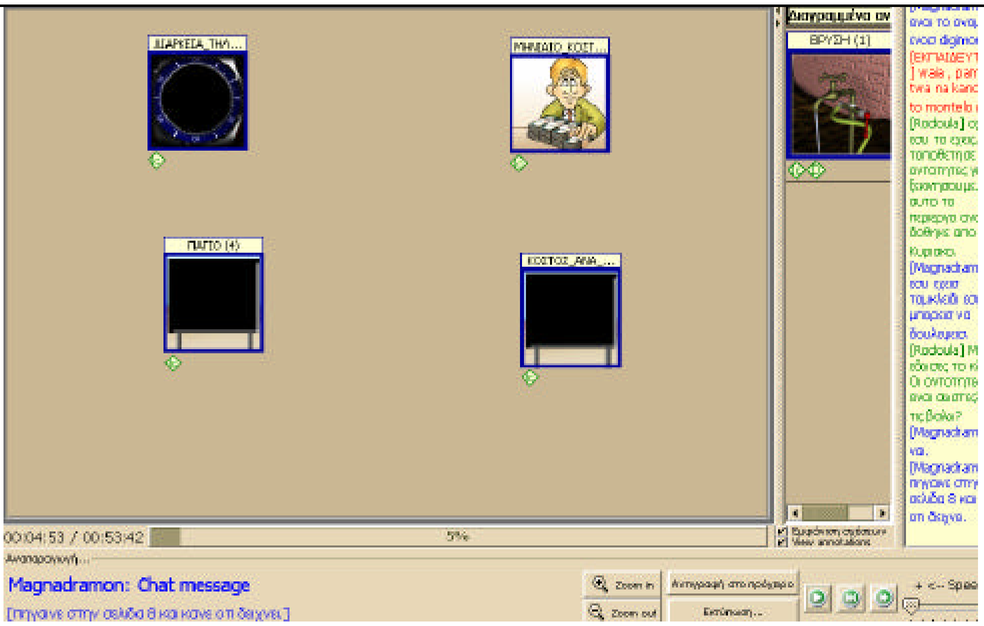
<table>
<tr>
<td>Statistics</td>
<td>


This tool besides the date of the session and who started the collaboration, gives information about:

key’s possession per user(percentage),

inserted entities and relationships

actions such as renaming, insertion, deletion, moving and chatting per user,

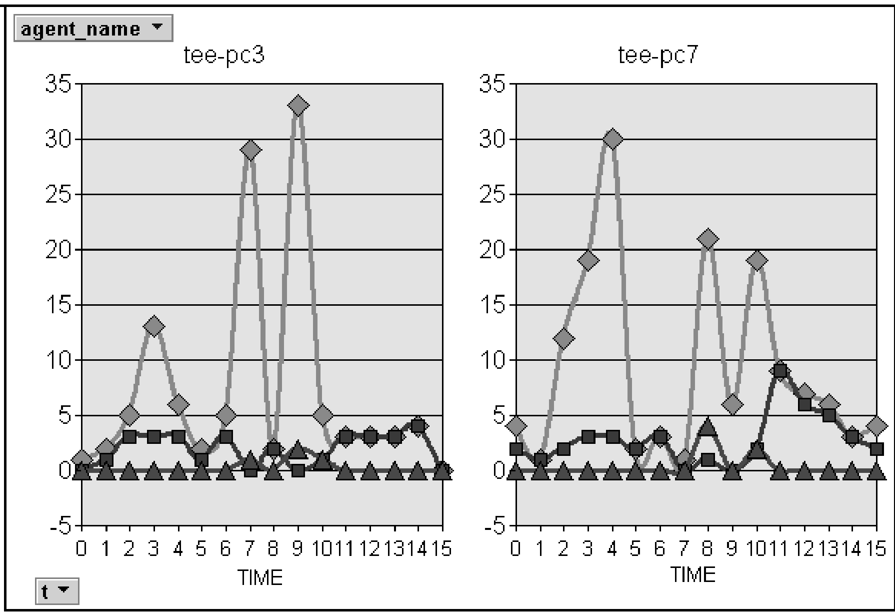
chat history
</td>
</tr>
<tr>
<td>Playback</td>
<td>


This tool allows the user to see the whole interaction process like a video tape along with some more possibilities:

Information about the owner of each object at the shared workspace,

Deleted objects’ history (chronological order of deletions, who inserted the object and who deleted it),

Zoom in, Zoom out, Speed adjustment, Copy to Clipboard and Print
</td>
</tr>
</table>

<table>
<tr><td></td><td>functionalities.</td></tr>
<tr><td>CAF</td><td>


Collaborative Activity Function is a special designed tool for the observation of the agents that collaborate through ModellingSpace. Teachers can use CAF tool in order to:
1. Estimate the total group activity.
2. The contribution of each agent.
3. The quality of the interaction according to the communication channel used.
CAF is basically counts the number of messages posted by the collaborating agents during a time period for each communication channel. Teachers can produce time diagrams of CAF for each agent and/or communication channel separately. Using CAF tool UI a teacher can select any combination of agents to compare. Finally teachers can zoom in specific time points. More about CAF interpretation can be found in the followings.
</td></tr>
</table>

	[00:04:53][Kyriakos] You must go to page 8 and do what it says. [00:06:23][Kyriakos] What's going on? Why you are doing nothing? [00:07:18][Rodoula] I can't put the relationship, I whould like some guidance. If you want ask for the key and do it. [00:07:26][Kyriakos] ?? **[KYRIAKOS TOOK THE KEY].** **[00:07:38][Teacher] Kyriako please, don't push Rodoula!**	 {KYRIAKOS DISPLAYED PROPERTIES AND VALUES}
COPRET	MS's log file was converted in a more readable print out form which contained: Chat history between students and between students and teachers (data from log file), Information about key's possession (data from log file), Snapshots of the shared workspace after an action like Insertion, Modification or Deletion occurred (using log file the researcher localize the time points that such action occurred and using Palyback Tool he captured the corresponding snapshots of the shared workspace). As a result, a Word file was produced, respecting the chronological order of events, containing teacher's interventions (messages or actions) as well as students' dialogues and actions.	

Table 5. ModellingSpace's Interaction Analysis Tools

6.7.1.1 Teachers' points of view for main tools

a. Context of data collection

The teachers that participated at our research, next table contains relevant information, were asked at the end of all sessions during an individual interview with each one, to comment on the main *Interaction Analysis Tools* supporting collaborative settings that they used.

School Names	Schools	ClassGroup	Number of pupils	Teachers' name	Disciplines taught
2nd TEE of Rhodes	*Secondary*	*TGP (K12)*	22	Anastassios SAVAS	Computer Science
		TAP (K10)	25	Demetrios KLADOGENIS	Computer Science
3rd Gymnasium of Rhodes	*Secondary*	*3G (K9)*	8	Elisabeth MAVROUDIS	Computer Science
5th Gymnasium of Rhodes	*Secondary*	*5G (K9)*	7	Xristos MITSOULLIS	Mathematics

Table 6. Teachers participated the research.

b. Statistics

b.1 Teachers' comments on Statistics.

Next table presents teachers' comments on Statistics during the interview at the end of all sessions.

6.7.1.1.1.1.1 STATISTICS	
Teacher 1 *said "The statistics are needed and useful but not enough on their own.* *Mainly you get information about the possession of the key".*	**General opinion** *[needed and useful, but not enough in its own]* **Information derived** *[key's possession]*
Teacher 2 said *"I would use statistics if I wanted information like the possession of the key".*	**Information derived** *[key's possession]*
Teacher 3 said *"Statistics give general information about collaboration, like percentage of key's possession, number of messages per participant.* *But can't come to safe conclusions about the collaboration unless you have access to other analysis tools".*	**Information derived** *[general information like key's possession, messages per participant]* **General opinion** *[for safe concussions, access to other analysis' tools]*

Teacher 4 said *"With Statistics you get <u>quantitative information</u> concerning collaboration, for example percentage of key's possession, number of messages per participant.* *I think that these information can be illustrated by CAF, since <u>Statistics are not sufficient in any case"</u>.*	**Information** *[quantitative/key's possession, number of messages per participant]* **General opinion** *[are not sufficient in any case]*

Table 7. Teachers' comments on *Statistics.*

6.7.1.1.2 b.2. Results Analysis on Statistics

Most of the teachers (three out of four) believe that Statistics seems to be a useful tool, but you can't get to safe conclusions unless you have access to other analysis tools. All teachers mentioned key 's possession. It is the one information that all teachers are noticed. The usefulness of this information is also confirmed by the use of this tool during the interactions' analysis sessions, Table 11, where for example Teacher1 said *"Micelle possessed the key more than Mary"*, or Teacher 3 *"Most of the time I had the key. Next time I will try to sent more messages"*.

<u>c. Playback tool</u>

c.1 Teachers' comments on Playback tool.

Next table presents teachers' comments on Playback during the interview at the end of all sessions.

6.7.1.1.2.1.1 PLAYBACK	
Teacher 1 said *"Playback is very useful for teachers and students when they <u>want to criticize a posteriori the work that has taken place</u>".*	**Modes of use-** *[for criticizing the work that has taken place]*
Teacher 2 said *"I would use Playback firstly, in order <u>to study a group's solution without time pressure,</u> and secondly if I wanted <u>to demonstrate to the students some points that need further discussion".</u>*	**Disadvantage:** *[time consuming]* **Modes of use:** *[demonstration to students for further discussion]*
Teacher 3 said *"Using this tool teachers watch students' actions during problem-*	**Mode of use:** *[localization*

solving and thus they are able to find the mistakes. With Playback is not easy to follow actions and dialogues that take place simultaneously".	*students' mistakes]* **Disadvantage:***[difficult to follow actions and dialogues that took place simultaneously]*
Teacher 4 said *"Using Playback you can follow students' problem-solving process. The problem is that it is time consuming and if you must do it for lets say ten groups then you need much time".*	**Information derived:** *[details from students' problem-solving process]* **Disadvantage:** *[it is time consuming]*

Table 8. Teachers' comments on *Playback.*

c.2 Results analysis on Playback

All teachers mentioned that Playback seems to be a useful tool. But, they find that it is not (a) easy to use, (b) time consuming.

That's why teachers during the interactions' analysis sessions used "Playback" once, mainly for localization and demonstration of students' mistakes (Table 13) and afterwards they used the other available tools, since "Playback" "didn't offer something more" as Teacher 2 said.

d. Collaborative action function Tool

d.1. Teachers' comments on CAF tool.

Next table presents teachers' comments on CAF during the interview at the end of all sessions.

6.7.1.1.2.1.1.1 CAF	
Teacher 1 said *"I think it is a useful tool. It is very important the fact that it contains not only quantitative but also qualitative parameters. For example the kind of action that is taken place at the shared workspace: the students are running the model, the students are inserting a relationship.* *Of course, in order the teacher to be able to make worthy all the functionalities, he needs a lot of practice.*	**General opinion** *[useful tool]* **Justification** *[quantitative & qualitative information]* **Disadvantage:** *[teacher needs practice]*
Teacher 2 said *"I would use CAF especially if I had to watch many groups at the same time. So I would be able to find out in time that a*	**Mode of Use [***overview-supervision of many*

group face problems and is doing nothing, or that a student monopolize the work and is not giving the key to other participants”.	*groups,]* **Information derived:** ***[****quality/equilibrium of collaboration****]***
Teacher 3 said *“First of all, CAF gives me an overview of the collaboration between students but also illustrates my behavior.*	**Mode of Use** *[overview-supervision of many groups]* **Information derived** *[teachers' behavior]*
As far as students' collaboration is concerned, a teacher can intervene in order to help when he sees that the curve is going down.	**Information derived** *[Curve down****]*** **T. Strategy** *[change the group members]*
Also you can use CAF for planning next lesson. If you repeatedly see that a group has “bad” collaboration then you probably must change the participants.	**T. strategy** *[intervenes less]*
As I already mentioned, I can evaluate my own interventions, for example if I intervene too often then I must leave students more on their own.	**Mode of Use-requirement** *[on line]*
Finally I believe that this tool must be available during collaboration (on-the-fly) especially if the teacher has to watch more than one group at the same time”.	**General opinion** *[gives a general idea****]***
Teacher 4 said *“CAF is giving you a general idea about the collaboration that has taken place, concerning students and teachers.*	**Mode of Use-requirement** *[on line]*
I believe that if the teacher can watch students during collaboration (on-the-fly) using CAF, then he can intervene in order to make the collaboration “better”.	

Table 9. Teachers' comments on CAF.

d.2. Results analysis on CAF

Teachers' global point of view about CAF, points out mainly:

(a) its usefulness, considering it as a tool presenting an overview,

(b) its justification, showing that one can derive qualitative information,

(c) teaching strategies that they can decide, based on CAF information,

(d) the interest in the mode of use 'on the fly', so as to supervise many groups at the same time.

e. COllaboration Progress REproduction Tool (COPRET)

e.1. Teachers' comments on COPRET.

Next table presents teachers' comments on COPRET during the interview at the end of all sessions.

6.7.1.1.2.1.2 COPRET	
Teacher 1 said *"I would definitely use this tool again because*	**General opinion :** *[very useful tool]*
it allows me and the students to criticize what we did, what we said.	**Information derived:** *[details from actions and dialogues]*
In this way we can find our weak points without time pressure, unlike during the collaboration where our decisions are under a lot of pressure.	**Mode of use:** *[localization of weak points]*
For the time being, I would not change anything. On the contrary, I would enjoy working with this new tool".	
Teacher 2 said *"I would use this tool again because it was the most useful collaboration's analysis tool.*	**General opinion**: *[the most useful collaboration's analysis tool]*
Mainly through dialogue study and actions analysis,	**Information derived:** *[dialogues' and actions' analysis]*
I concluded each member's participation during problem-solving and their weak points concerning the subject matter that was taught".	**Mode of use:** *[estimation of each member's participation and localization of students' weak points]*
Teacher 3 said *"I would use this tool for studying, analyzing, students' behavior.*	**Mode of use:** *[studying and analyzing students' behavior]*
Using this tool you overcome the problem (that I	**Information derived:** *[attendance of actions and*

noticed using Playback), concerning the difficulty to follow actions and dialogues that take place simultaneously. *The data are presented in a readable and usable manner. It is very important the fact that you can find weak points and misconceptions concerning the subject matter that was taught".*	*dialogues]* **Mode of use:** *[localization of students' weak points and misconceptions]*
Teacher 4 said *"After using CAF, if someone wants to "see" more details concerning collaboration but also students' aspects*	**Information derived:** *[details concerning collaboration and students' aspects]* **Mode of use:** *[localization students' misconceptions]*
or misconceptions concerning a specific topic you have to use this tool.	
Additionally teacher can either criticize his own interventions or study their results.	**Mode of use:** *[criticizing teacher's interventions, studying interventions' results]*
Using this tool, unlike Playback, you can have fast enough a detailed perception of the whole process that took place during collaboration".	**Mode of use:** *[detailed perception of the whole process]*

Table 10. Teachers' point of view for COPRET.

e.2. Results analysis on COPRET

Teachers' global point of view about COPRET, points out mainly:

(a) its usefulness considering it as a tool presenting details from dialogues and actions during collaborative problem-solving,

(b) its justification, since teachers can:

1. localize students' weak points and detect misconceptions,
2. studying students' behavior and contribution,
3. criticize theirs interventions and analyzing interventions' results.

6.7.1.2 How teachers used the tools

At the end of each session, the researcher was providing teachers with collaboration analysis data separately for each analysis tool. The data concerned students that worked OME and OXE modes of use (see section D. Context of study).

At the following tables, we present teachers' comments during reflection on collaboration analysis data along with the information they decoded, that means the information that appeared 'useful' to them and how they regulate their strategies taking into account te information from tools' usage.

STATISTICS	
"Useful" information for teachers	**Key's possession for teachers' own assessment:** *"Most of the time I had the key"* Teacher 3. *"Well, I had the key, but most of the time students had it"* Teacher 2 **Key's possession for comparison among collaborative members:** *"Micelle possessed the key more than Mary"*, Teacher 1. *"You see, the collaboration seems good, students possessed the key equally"* Teacher 4. **Number of messages per participant for teachers' own assessment**: *"I sent most of the messages too"* Teacher 3**.** **Number of messages per participant for comparison among collaborative members:** *"…but Mary sent more messages"*, Teacher 1 *"Let's see the number of messages…"* Teacher 2.
Regulation of teachers' strategies	**Teachers' own assessment**: *"Most of the time I had the key. Next time I will try to sent more messages"*. Teacher 3

Table 11. How teachers used "Statistics".

The above table presents all teachers' speech acts that concern the "Statistics".

We can notice that teachers observe mostly key' possession and number of messages per participant for comparison among collaborative members and for their own assessment.

They read this information in order to have a rough idea about the "kind" of collaboration that occurred and for regulating their own behavior.

CAF	
"Useful" information for teachers	**Students' collaboration assessment:** • *"It is obvious that Kyriakos dominated at all phases of the activity. Helen was too silent…"* Teacher 1. • *"You can see that any action was made by Katsouraki, Kornaropoulos did nothing"*, Teacher 3. • *"Even though students were working all alone, collaboration seems pretty good"*, Teacher 4. **Self-assessment:** • *"Well, I had a lot of action, you can see it. But there were cases that students stacked as we can see, I did something and they continued"*, Teacher 3. • *"I dont't think I was intervening too often, especially during the phase of answering the questions"*, Teacher 1.
Regulation of teachers' strategies	**Self regulation:** • *"I didn't intervene too much, I want to continue like this"*, Teacher2 **Planning - Group formation:** • *" I have to change Kyriakos' partner, I have to find one who will be more dynamic"* Teacher 1. • *"Mary and Micelle, although they were working alone, seems to had a good collaboration, I will not make any change"*, Teacher 1.

Table 12. How teachers used "CAF".

The above table presents all teachers' speech acts that concern the "CAF" diagrams (for example see figures in G.II.1 above). We can notice that teachers observe mostly the contribution of each participant, students and teachers. How "active" each one was, as far as actions and dialogues is concerned, since now they can have qualitative information about the collaboration, like the degree of groups' collaborative activity, or each participant's actions including him/herself. As a result, the teacher was able to diagnose collaboration quality or cognitive problems, plan his/her interventions and assess students' contributions or his/her own interventions. CAF provides feedback about the style each teacher adapts during collaboration, for example if he/she was dominating or encouraged collaboration.

PLAYBACK	
"Useful" information for teachers	**Students' mistakes**: • *"Here they did it all wrong, you see, Kyriakos put the relationship wrong, Rodoula continue….",* Teacher 1. • *"They don't know how to do a graph?"*, Teacher 4.
Regulation of teachers' strategies	**Demonstration to students**: • *"I 'm curious what they will say when they see it next time"*, Teacher 3. • *"I think this tool is especially for students",* Teacher 2.

Table 13. How teachers used "Palyback".

The above table presents all teachers' speech acts that concern the "Playback". We can notice that teachers observe mostly students' mistakes during problem-solving in order to do a demonstration to students.

It is obvious that teachers' comments about "Playback" are few, in comparison to other tools. This is because using "Playback" was very time-consuming, so teachers used it once and afterwards they used the other available tools, since "Playback" "didn't offer something more".

COPRET	
"Useful" information for teachers	**Dialogue and actions' analysis for:** **(a) Collaboration assessment**: • *"Rodoula asked for help but he continue working",* Teacher 1. • *"Athina was not paying attention…"*Teacher 4. • *"all messages were about the key"*, Teacher 3. • *"Both students were explaining their actions",* Teacher 2. **(b) Knowledge assessment**: • *"They can't find the independent "*, Teacher 3. • *"They didn't know how to use Value Table"*, Teacher 1. **(c) Teacher's interventions assessment:** • *"This is mine mistake, I shouldn't give the information, I should wait"*, Teacher 1. • *"May be I should help them more to make the model, it was the first time.."* Teacher 4.

Regulation of teachers' strategies	**Self regulation**: • *"Next time when they ask me something, I will encourage collaboration instead of telling them what to do"*, Teacher 3. **Planning - group formation**: • *"Kyriakos worked much better with Rodoula, they will continue as a team*", Teacher 1. **Planning – off line interventions:** • *"Here its obvious that I have to explain again which variable is the independent and which one is the dependent. They don't know how to insert a relationship"*. Teacher 3 • *"They didn't' t use the model in order to answer the questions, they did calculations»*. Teacher 1.

Table 14. How teachers used COPRET.

We can notice that teachers observe mostly details from dialogues between participants and actions at the shared workspace. So teachers can have more than a general estimation about collaboration quality and an informing about the existence or not of cognitive problems. Using this tool, the teachers view the details of a problem-solving interaction between participants. This is very important for them, because making the learning process of a group explicit; the teacher can be aware of students' weak and strong points and thus be able to intervene accordingly. Additionally teachers can assess their own interventions and regulate their behavior after studying the results of each intervention.

6.7.2 G.II. The meaning, the quality, and the strategies of Synchronous collaborative problem solving through MS, among collocated participants

Until now, most of the studies on teachers' role have been focused on networked computer supported collaborative learning scenarios: asynchronous tutoring, where the teacher studies the students' interactions and then intervenes at a distance across the network in order to help them (Lipponen, 1999), or synchronous tutoring, where the teacher observes (at a distance) the students' interaction in real-time, and intervenes to help them (Lakkala, et al., 2001; Baker, et al, 2001). In both cases, the teachers are not in the same room with the students.

The present research aims at exploring synchronous computer mediated collaborative problem solving in real school context, with collocated students, in every day practice.

We focus with collocated students and teachers because:

1. We think this approach is valuable to schoolteachers because it provides teachers with some new opportunities, in spite of certain difficulties, such as time consumption. This is because learners interact through messages, and this information is available to the teacher as a resource that can be used to assess the learning that has taken place.

2. In this way synchronous computer supported collaborative learning is an integrated part of the whole learning environment, so teachers and students will participate more willingly and that luck of time will not be an excuse, like other researches.

Our analysis showed that the usage of a MS for collaborative problem solving with co-located participants is legitimated because:

(a) Students are motivated to do it

(b) Teachers' point of view related to this collaboration among collocated students is positive.

(c) The quality of interaction and collaboration among students give strong evidence to the point that students experience a high quality learning activity that activates high order thinking and negotiation skills.

(d) Analysis of teachers' interventions and strategies during collocated collaborative scenarios showed that this approach provides teachers with new opportunities since students' dialogue and actions are available to teachers

(e) Students' positive point of view and the declared wish to participate again in collaboration using ModellingSpace.

In the followings, the motivation of students is documented using a specially designed collaboration activity analysis tool and the teachers and students opinions, then the quality of the collaboration is analyzed in terms of the agents dialogs for a typical instance of each mode of use, after this the teachers interventions and their consequences during collaboration is analyzed and finally the main conclusions about the learning characteristics of the collocated use of ModellingSpace is summarized after the modes of use comparison.

6.7.2.1 G.I?.1. Are Students motivated to do it?

Students are actively engaged in collaborative problem solving using MS. The following diagrams give strong evidence for this argument. The curves in the diagrams have been specially designed as a collaboration analysis tool for ModellingSpace. The diagrams are constructed using data from the log file of MS. Every action of any agent creates a separate record in the log file. In the following sections students motivation is documented using collaborative action diagrams first and then with the analyses of the dialogs and especially by the estimation of the irrelevant to the problem solving dialog percentage.

a. Students' motivation in collaboration activity curve terms

In any of the following diagrams the following three curves appear:

1. The **interaction curve** counts any action in the log file for the given agent for a specific time quantum. The time quantum in this case is 240 seconds. If the agents are actively engaged in a quantum they produce interactions. The more the actions of an agent the higher the interaction curve. If there is no action in a time quantum the interaction curve is grounded to 0. Since every action counts for the formulation of interaction curve it could be high even students are just chatting. This problem could be avoided using the following curve.

2. The **chat_msg curve** counts for each quantum the number of chat messages posted by the specific agent. The chat_msg curve gives an indication for the quality of the interaction. Chat curve is always smaller or equal to the interaction curve. If chat curve is equal to the interaction curve students are just posting chat messages.

3. The **run curve** counts the number of run button presses produced by the specified agent in each quantum. The run button press is a very significant event during modeling development because it signals the time point where students probably have the first version of their model and they begin to review it.

Using the above information about he meaning of the curves that appear on the following diagrams we can support the following:

1. Students are actively participating to the learning activity using MS through out the duration of the activity. This is true for all modes of use (with or without teacher).
2. It seems that students are first collaborating in order to develop the model and after the model development they are mainly chatting reflecting on the model in order to answer the questions in the activity sheet. For example in figure 1 students are developing the model until about the 11th quantum (44 minutes) while they are chatting for the rest of the time for the answer of questions exploiting the model execution.
3. Agents are active not only in chatting but to modeling using MS representation system. Further more none of the agents is dominating the

action but in most cases all agents have significant contribution through out the activity duration.

4. Agents can be actively participating for long intervals as appears in the figures (up to 19x4 minutes).
5. The above observations show that students can successfully use the MS software environment to implement high motivated collaborative modeling learning activities.

a.1. Collaborative activity diagrams for typical instances of OME mode of use.

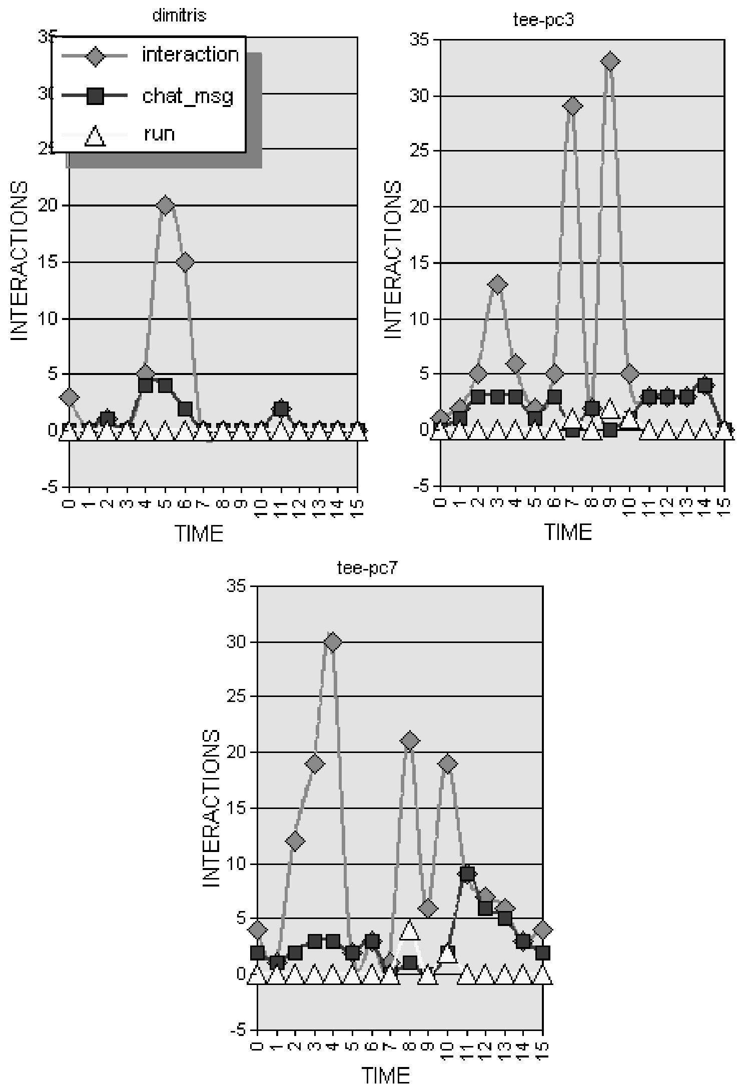


Figure 2. Interaction diagrams for a group of two students (tee-pc5, tee-pc7) and a teacher (Dimitris). 24/11/2003 in TGP, Activity 1.

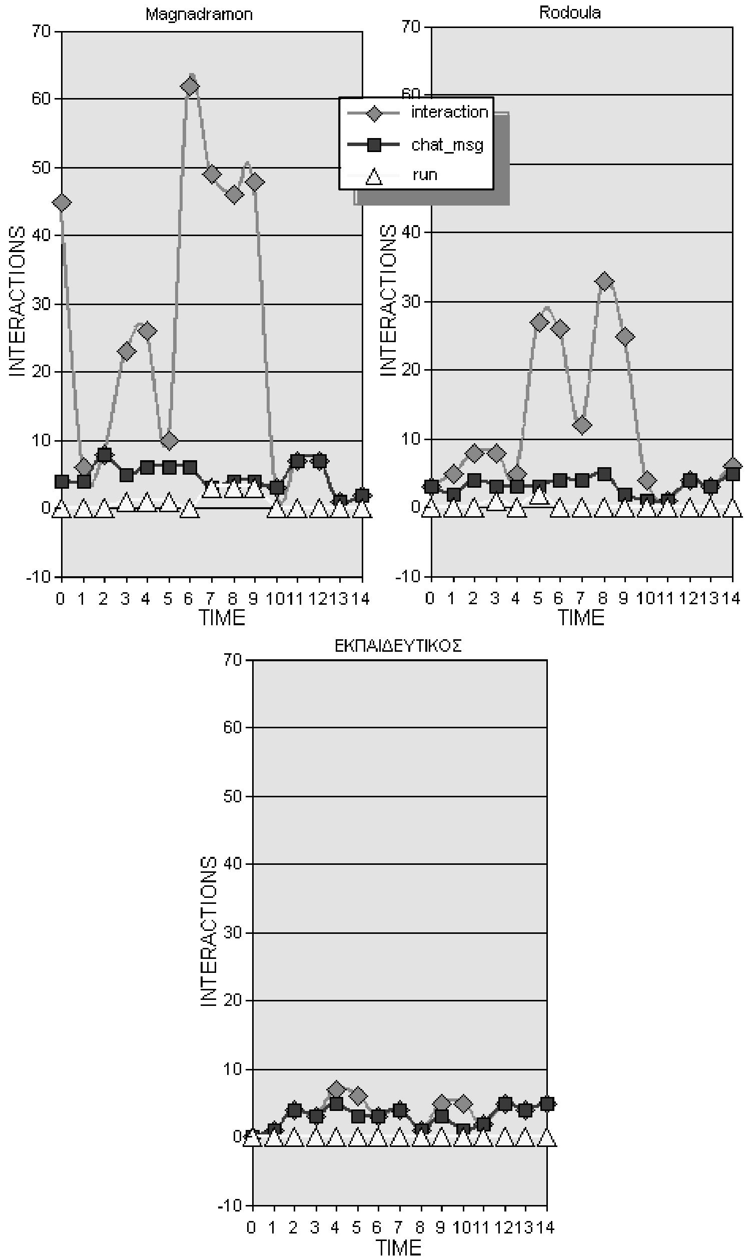


Figure 3. Interaction diagrams for a group of two students (Magnadramon and Rodoula) and their teacher. 19/01/2004, 5G, Activity 3.

Students are active from the first to the last quantum. Furthermore students are taking the initiate in turn from each other. Agents in the first case have comparable contribution while in the second the first student seems to hold the mouse for longer periods. Students are reflecting for a long time interval after the quantum 11 in order to exploit the model in problem solving. In that period students are engaged most in social negotiation through chat. Teachers have a rather discreet in order for the group to keep collaborating. In traditional classes it is a rather unusual phenomenon for students to be active for so long (60 minutes minimum).

a.2 Collaborative activity diagrams for typical instances of OXE mode of use.

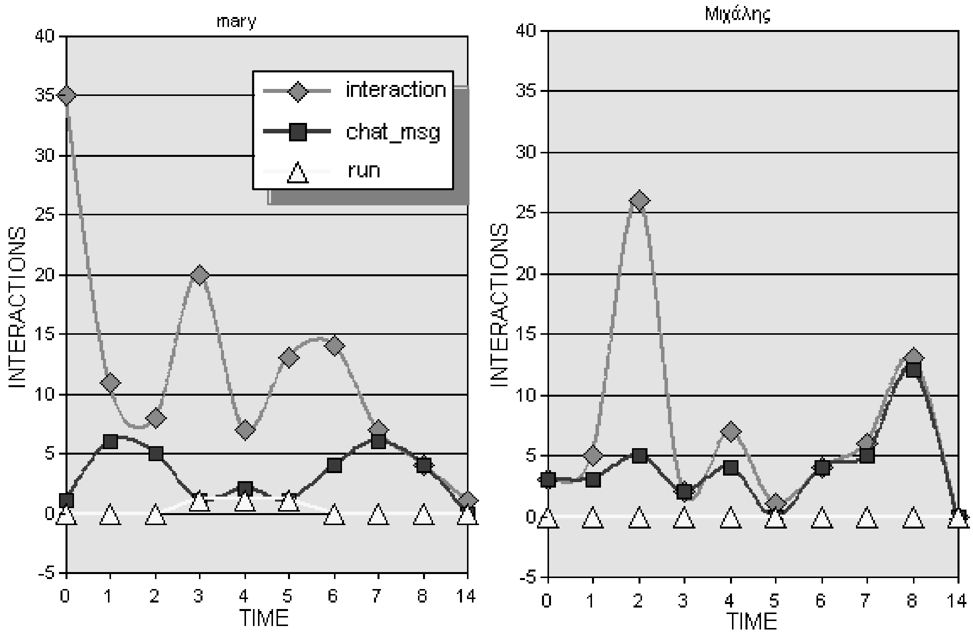


Figure 4. Interaction diagrams for a group of two students (Mary and Michael) without the participation of a teacher. 17/01/2004, 5G, Activity 2.

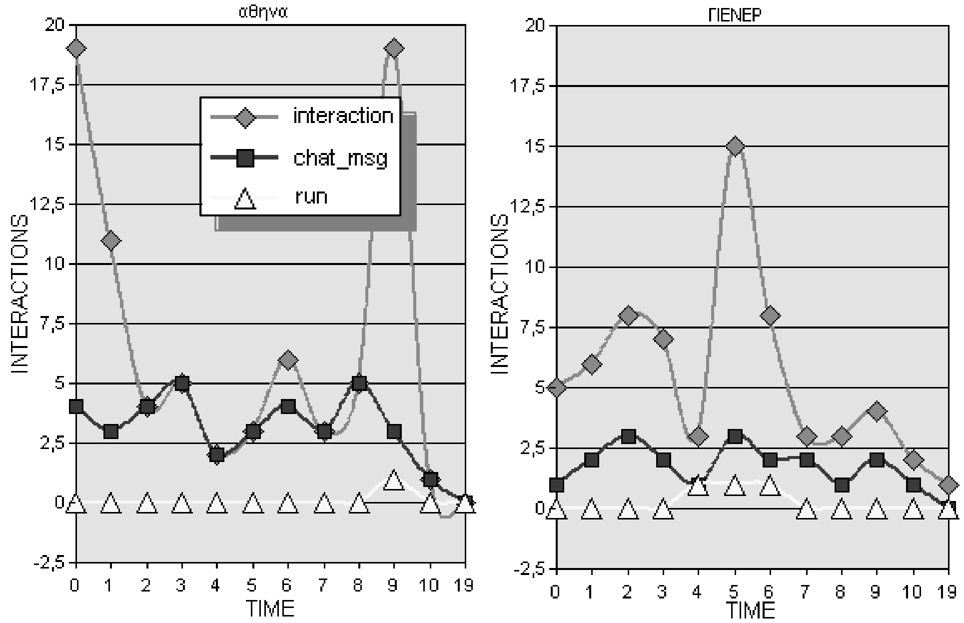


Figure 5. Interaction diagram of two students (Athina, Giener). 12/12/2003, TAP, Activity 2.

In the above collaborative activity diagrams we can see that even without the presence of a teacher students are actively engaged in the problem solving using MS. Students are taking initiative in turn from each other to modify the model in the common workspace while they constantly chat in order to negotiate, exchange and construct knowledge. Students are working for more than 60 minutes.

a.3. Collaborative activity diagrams for typical instances of OXE mode of use.

In the case of the more than one student in front of a pc collaborating with a similar subgroup in another pc under the supervision of a researcher students where also motivated but they didn't manage to form a common group. The students constituted to separate groups (one for each pc and researcher) that where cooperating rather collaborating.

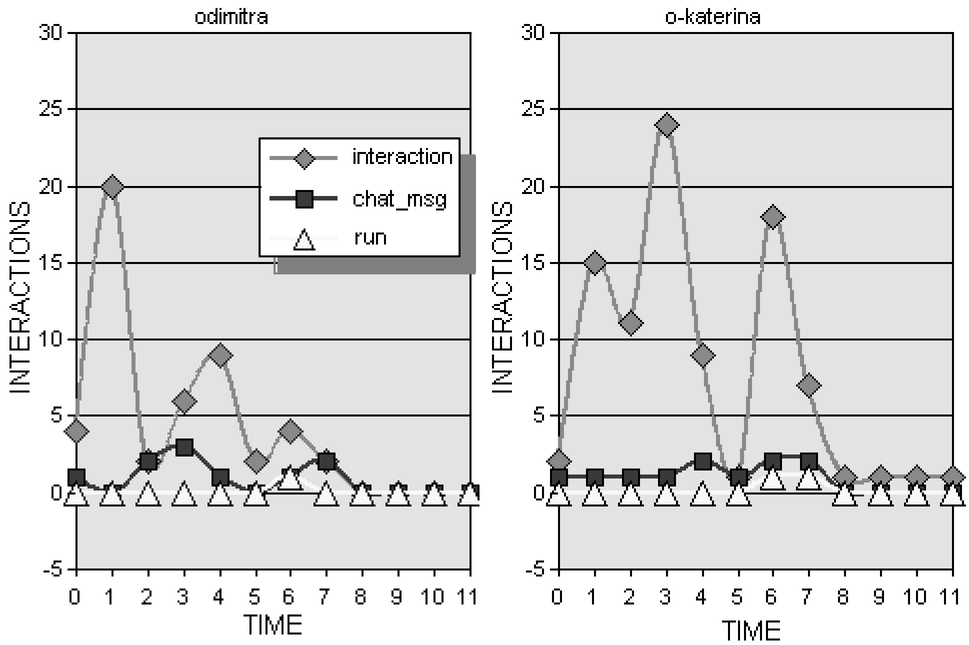


Figure 6. Interaction diagram of two groups of students under the supervision of researchers (dimitra, katerina). 12/12/2003, TAP, Activity 2.

In the above diagram we can see that the two groups are exchanging minimum number of chat messages in order to coordinate the model constructions while they are not communicating at all in the phase of problem solving (after quantum 8). This is a typical case of cooperation in terms of the collaborative action curve. The OMR mode of use will be analyzed further below.

b. Students motivation in dialogue analysis terms

Strong evidence for the motivation of students can be formulated by the qualitative analysis of the agent's dialog. In the following pie charts we can see the frequency distribution of the chat messages in to qualitative categories. For the categories detailed explanation see section G.II.3.1. The pie titled OME concerns of a group of two students with a teacher (19/1/2004, 5G, Activity 3), the pie titled OXE concerns a group of two students (19/1/2004, 5G, Activity 3), and the pie titled OMR concerns the collaboration of two groups of two students and a researcher each collaborating using two PC's (12/12/2003, TAP, Activity 2). It is obvious that students exchange chat messages about the project and only a small percent of the messages are irrelevant to the problem. The irrelevant messages are categorized as "unclassified" and "social conversation". The percentage of these categories is practically insignificant when students are communicating only using MS (OME, OXE) while is increasing to 31% when students have also the opportunity of face to face communication (OMR).

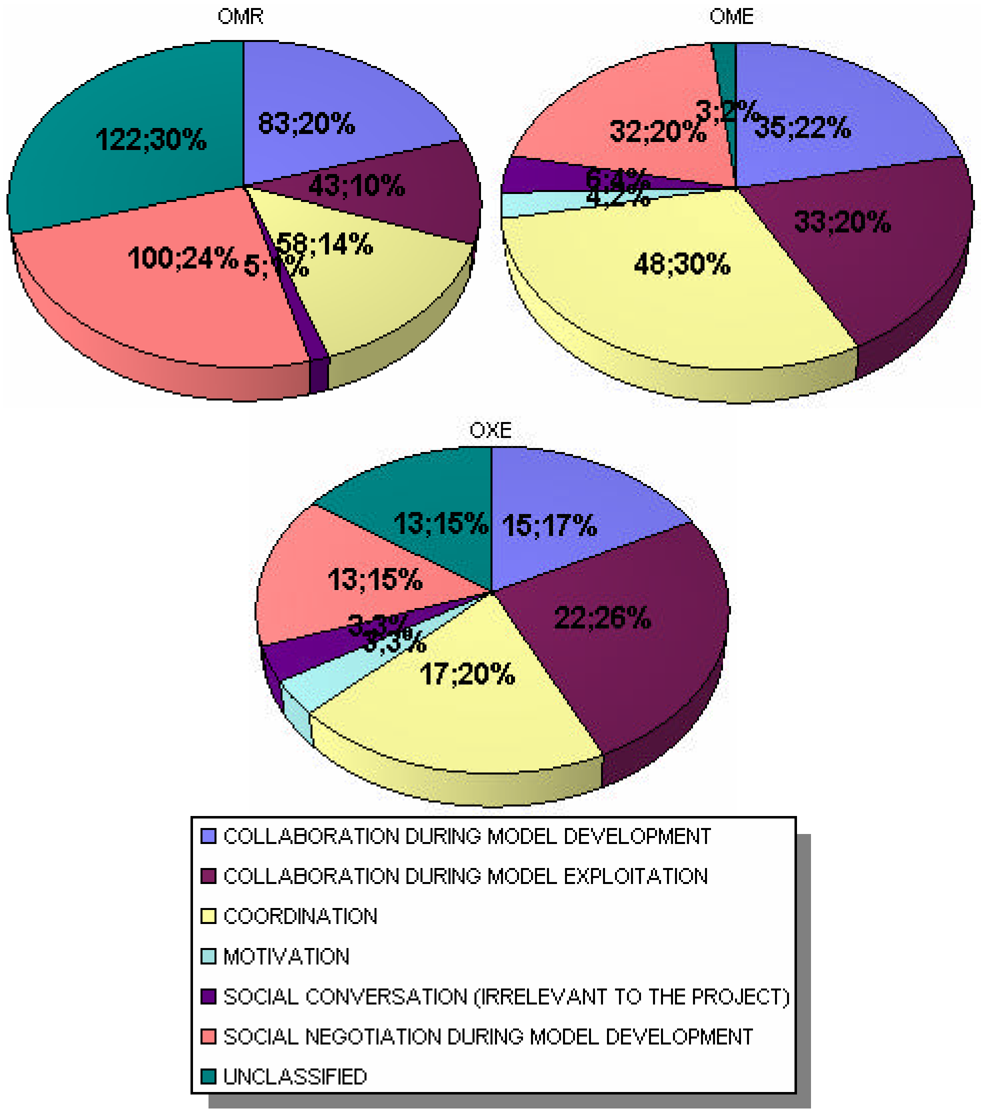


Figure 7. Qualitative analysis of the students dialogs during learning activities. Student's messages distribution to categories. The students dialog quality depicts the active engagement in a high quality collaborating learning activity with many opportunities for social negotiation skill advance.

c. Teachers' opinion on students' motivation

According to teachers' questionnaires at the end of the session we have the following graph:

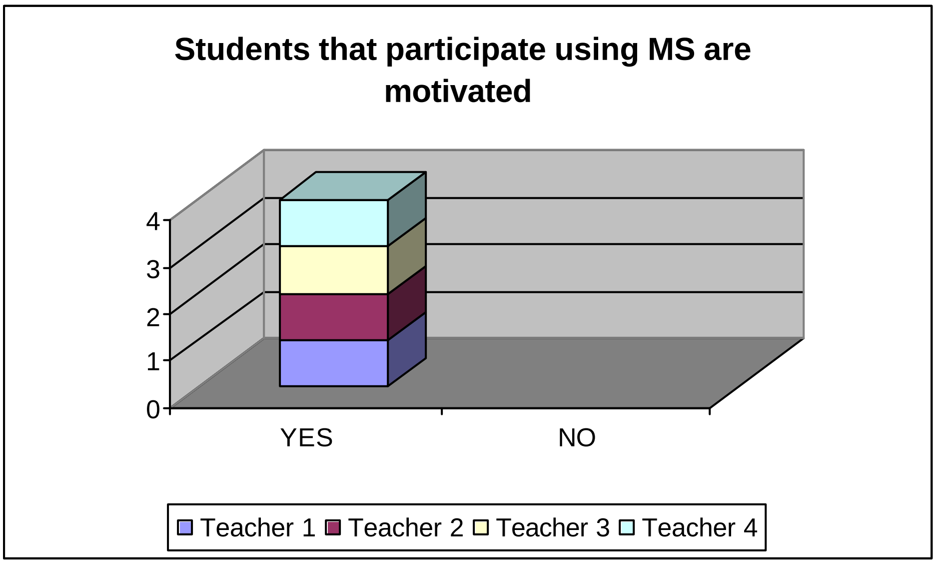


Figure 8. Teachers' answers to the question: Are the students that participate using MS motivated?

All teachers agree that the students that participate using MS are motivated.

d. Students' answers from questionnaire

According to students' questionnaires at the end of the session we have the following:

d.1 *Question*: According to your opinion, what are the advantages of computer supported collaborative problem solving in comparison with face-to face collaboration.

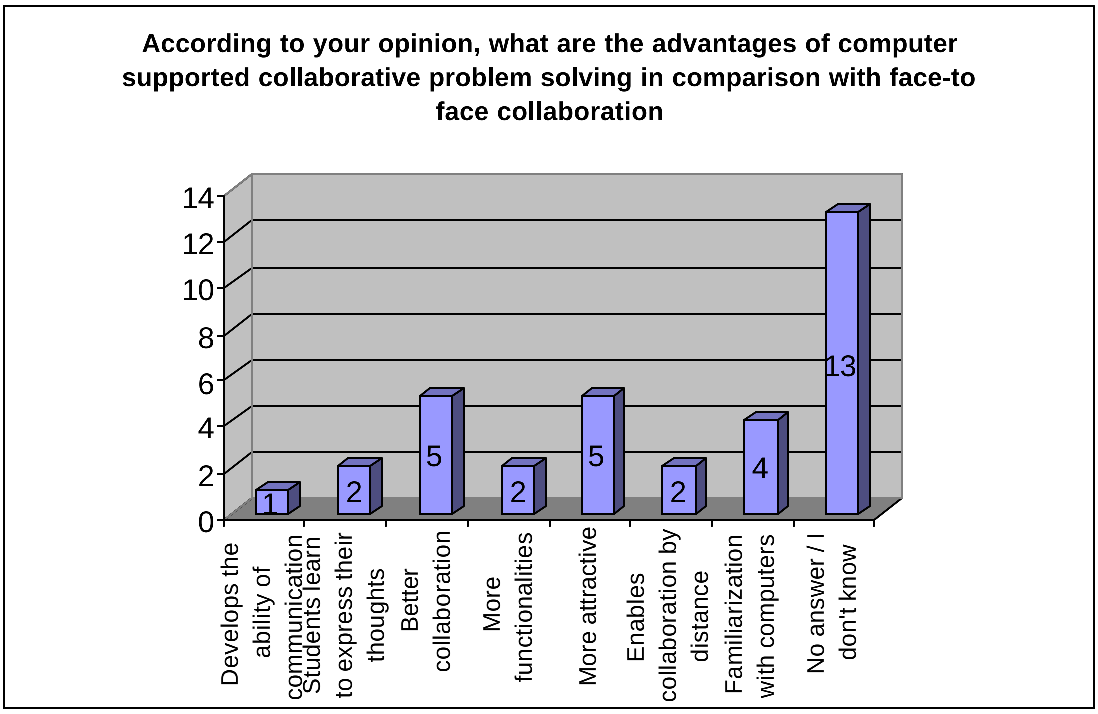


Figure 9. Students' answers to the question: "According to your opinion, what are the advantages of computer supported collaborative problem solving in comparison with face-to face collaboration?".

Students' answers to the category:

(a) **Develops the ability of communication** were *"Develops the ability of communication between students".*

(b) **Students learn to express their thoughts** were *"Develops the way students express their thoughts", ""Students must explain to their participants every though, so they learn to be explicit and to use the right terms*".

(c) **Better collaboration** were *""There are not off-task messages', "Better concentration", "We learn to collaborate, more profitable collaboration", "Better understanding", "Attendance of other participants' actions".*

(d) **More functionalities** were *"By using computer more information are available", "We have more possibilities by using computers"*

(e) **More attractive** were *'I find this way of working more attractive", "this way of working is totally different from the way we are used to work up to now, and I like it".*

(f) **Enables collaboration by distance** *were "This approach enables collaboration by distance".*

(g) **Familiarization with computers** were *"Working in this way we familiarized with computers"*

In computer supported collaborative learning unlike face to face collaboration participants communicate through written messages, something that according to most students' opinion develop the ability of communications, students learn to express their thoughts, minimize off-task messages, students are more concrete and attend other participants' actions. Some find this way more attractive, out of the usual. Some other noticed the possibility of collaboration by distance while other think that it is just an opportunity to be familiarized with computers.

d.2 Question: Do you want to participate again and why?

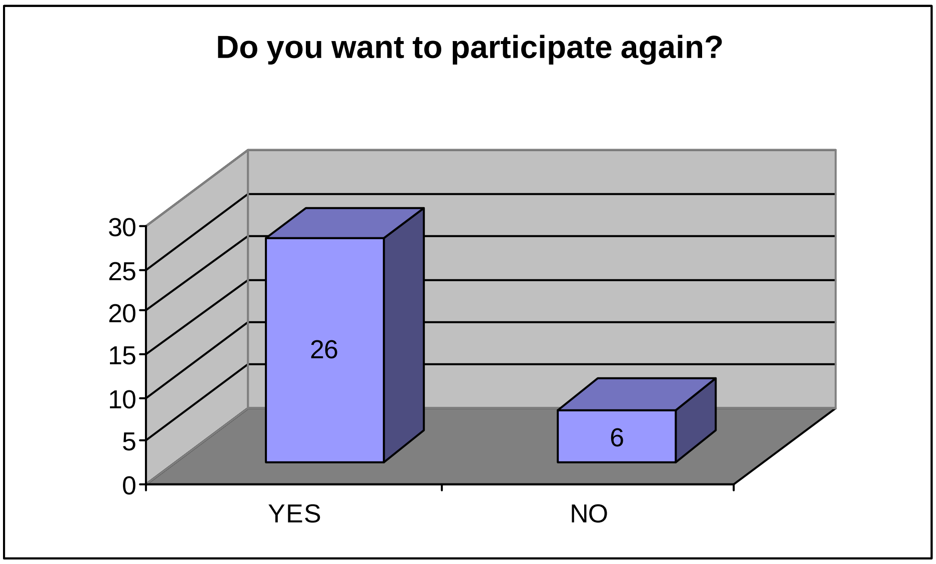


Figure 10. Students' answers to the question: Do you want to participate again using this kind of collaboration?

We can see that most of the students (more than 80%) want to participate again. The reasons they gave are the following:

(a) One student answered, *"We learned to collaborate and to communicate"*

(b) Three students answered, *" We learned things collaborating in this way"*

(c)One student answered, *"Collaborating in this way we learned what collaboration means"*

(d) One student answered, *"It was interesting because we were discovering our knowledge"*

(e) One student answered, *It will be useful for the future"*

(f) One student answered, *"Creative activity"*

(g) One student answered, *"I prefer to be helped by my classmates"*

(k) Two students answered, *"I liked this kind of collaboration"*

(l) Six students answered, *"Very nice experience"*

(m)Two students answered, *"Students are motivated"*

(n) One student answered, *"Familiarization with computers"*

The rest of the students didn't justify their answer.

From the above students' answers there are very interesting points concerning justifications based on collaboration (e.g. *"We learned to collaborate and to communicate")*, and on metacognition (e.g. *"It was interesting because we were discovering our knowledge"*) .

The students that don't want to participate again (less than 20%) gave the following reasons:

(a) One student answered, *"I didn't like it very much"*

(b) One student answered, *"It was boring"*

(c) One student answered, *"I am not used to writing using computers"*

(d) One student answered, *"I don't like collaboration, I prefer solving problems alone"*

The rest of the students didn't justify their answer.

As we can see, one student expresses the possible difficulties of students on writing, as a more cognitive demanding activity. Another one prefers to work alone.

These answers are going to be further examined in the future.

d.3. *Question*: In which cases/lessons this kind of collaboration is appropriate to be applied?

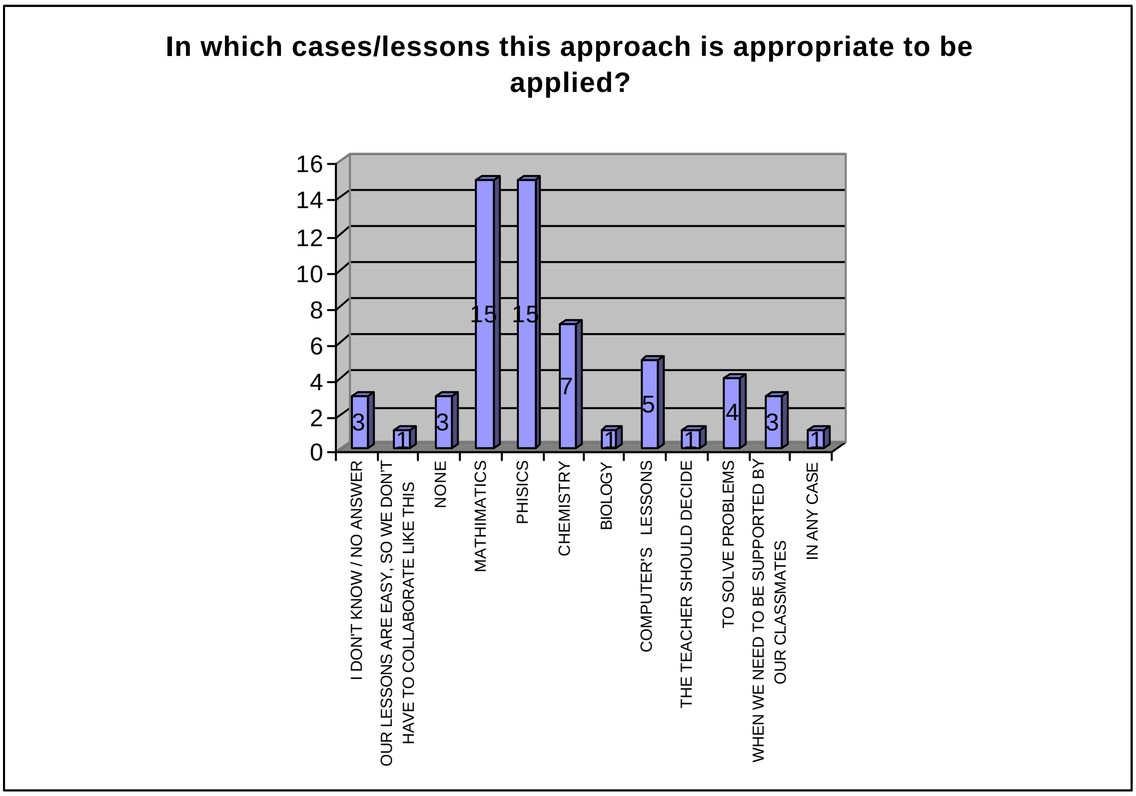


Figure 11. Students' answers to the question: In which cases or lessons this approach is appropriate to be applied?

We can see that almost 80% of the students believe that computer-supported collaborative problem solving with co-located participants is appropriate to be applied at school lessons.

Concretely:

(a) Three students didn' t answer
(b) One thinks that *'Our lessons are easy so we don't have to collaborate like this'*.
(c) Three students answered to *'None'*.
(d) Fifteen suggested *'Mathematics'*.
(e) Fifteen suggested *'Physics'*.
(f) Seven suggested '*Chemistry*'.
(g) One suggested '*Biology'*.
(h) Five suggested '*Computer lessons'*.
(i) One answered '*The teacher must decide'*.
(j) Four answered '*When we want to solve problems'*.
(k) Three answered '*When we need to be supported by our classmates*'.
(l) One answered *'In any case'*.

The higher numbers are for maths, physics, chemistry and computer lessons. Four students answered that this approach is suitable for solving problems. It is obvious that most of the students believe that this approach is suitable for problem-solving.

d.4. *Question*: How about using this kind of collaboration with your classmate after school?

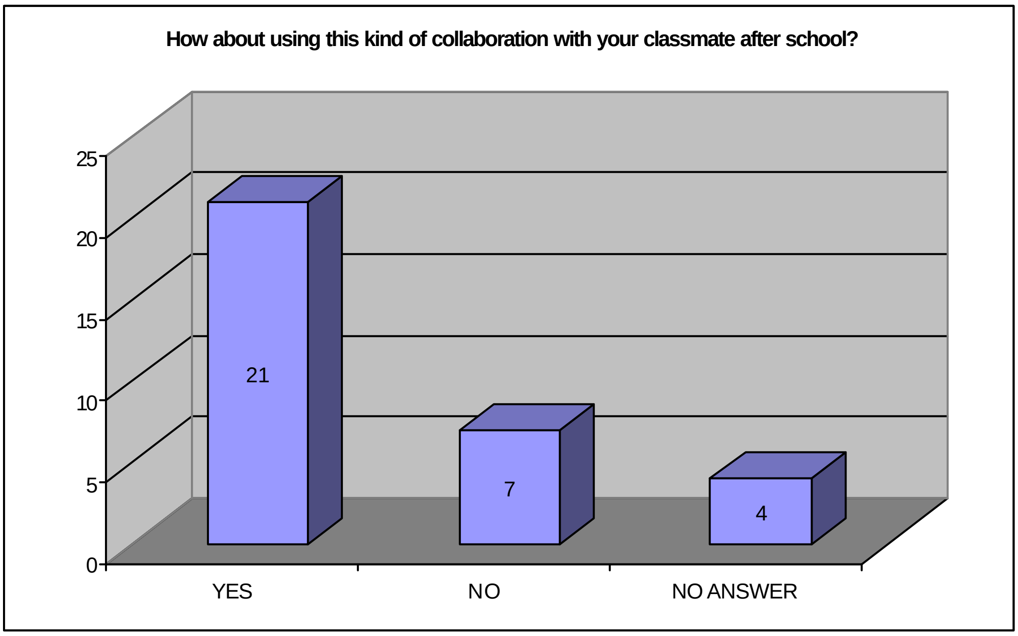


Figure 12.. Students' answers to the question: "How about using this kind of collaboration with your classmates after school, from your home for example"

We can see that most of the students (more than 65%) are positive about using this kind of collaboration with their classmates after school.

e. Conclusions about the students' motivation

According to the research data students are highly motivated to use ModellingSpace in collocated learning activities since they are engaged for long time periods in productive problem solving. Students can easily communicate using ModellingSpace means in most modes of use but they face difficulties to formulate a total group in case of OMR mode of use. Students in OMR prefer to collaborate by face to face communication rather than through ModellingSpace and so they formulate two cooperating groups. As will be shown in the followings the quality of face to face collaboration is rather lower than online (G.II.3).

As far as the students opinion is concerned students believe that this approach gives possibilities for better collaboration and communication, find this way attractive and believe that computer supported collaborative learning is appropriate to be applied at school lessons. Finally students' motivation is expressed through their willing to participate again in collaborative activities using ModellingSpace.

6.7.2.2 G.II.2. Teachers' point of view related to this collaboration among collocated students

According to teachers' questionnaires at the end of the session we have the following:

a. Question: According to your opinion, what are the advantages of computer supported collaborative problem solving in comparison with face-to face collaboration.

Teacher 1 wrote*: "…with this approach students' thoughts and concepts are registrant".*

Teacher 2 wrote: *"I think that the biggest advantage of this approach are the collaboration's analysis tools that are available to teachers and the positive students' attitude towards this approach".*

Teacher 3 wrote*: "…teachers can attend students' collaboration and problem solving so he can intervene more effectively".*

Teacher 4 wrote: "Firstly *students' thoughts and concepts are registrant and secondly off-task messages are inexistent".*

So, according to teachers' opinion, the advantages of this approach are:

(a) Students' dialogues and actions availability.

(b) Positive students' attitude

(c) Inexistence of off-task messages.

b. Question: When during the teaching process do you consider that computer supported collaborative problem solving is appropriate be to applied?

Teacher 1 wrote: *"If you want to use this approach you must design the appropriate activities that will urge students to argument".*

Teacher 2 wrote: *"I can use it from time to time as an alternative way of teaching, with activities suitable for collaborative learning".*

Teacher 3 wrote: *"Of course I can't use it every day because it is time consuming. I can use it to check students' thoughts on basic concepts and procedures".*

Teacher 4 wrote: *"I think this approach is valuable especially in cases you need to check students' concepts, what they haven't understood, what they have misunderstood. Of course you need the appropriate activities".*

Teachers notice that this approach can be applied:

(a) If the teacher designs the appropriate activities.

(b) As an alternative way of teaching.

(c) For checking students' concepts and misunderstandings.

c. Conclusion

Teachers' point of view about collaboration among collocated students is positive since: (a) students are motivated, something that is proved according to their opinion by the inexistence of off-task messages and students' positive attitude, (b) unlike to face-to-face collaboration students' dialogues and actions are available.

Additionally teachers notice that if they design the appropriate activities, this approach can be applied as an alternative way of teaching, for checking students' concepts and misunderstandings.

6.7.2.3 G.II.3 The quality of interaction and collaboration among students

Students are motivated to active engagement in collaborative learning activities using MS. This fact generates the following questions:

- What is the quality of this collaboration form an educational point of view?
- Is there any significant affection of the mode of use in the quality of the collaboration?
- Does the system impose any style in the teaching or learning process administration?
- Do students always collaborate or it is possible to develop competition conditions?

We are going to approach the above questions by qualitative analysis of the agents' communication during the learning activities implementation. For the analysis of the oral and written dialogue a hierarchical system of messages categories is defined and then each of the messages that has been logged by the system or recorded in the audio-tapes is categorized in order to produce the corresponding frequency distributions. We choose three typical cases to analyze corresponding to the three modes of use. In the followings first the hierarchical system of messages categories is presented and then the analysis of the dialogues and finally the conclusions in correspondence to the above questions.

6.7.2.3.1

6.7.2.3.2 G.II.3.1 The formulation of the classification system for the messages of the dialogues

6.7.2.3.3 a. The dialogue structure

For the formulation of the classification system we separate the collaboration in two main phases:

Phase 1. During phase 1 the agents are developing the model for the physical system of the project problem. Phase 1 finishes at the first successful execution of the model.

Phase 2. During phase 2 agents are exploiting the model in order to answer the questions of the project problem.

The quality and the structure of the dialogue are different among the two phases and it is purposeful to be analyzed appropriately. For the description of the dialogue structure we need to get in a level of abstraction higher than the single statement-phrase. It is possible to discriminate small atomic episodes-extracts that concern different aspects of the collaborative problem solving project using MS. Using this approach it is possible to define the detailed categories of messages for each structure unit. All these are going to be clearer in the followings where we present the structure of the dialog in each phase.

b. The structure of the dialog during phase 1 (model development).

During the first phase agents dialogue episodes are basically of the following kinds:

1. *Project management*

Agents are in charge to manage the project in hand so they often exchange messages for relative matters. The messages are classified in the following categories: *Planning, Scheduling, Assignment, Auditing.* These categories follow the usual process model of the project management and permit the estimation of the administrative role of each agent and the style of administration of the project (democratic or centralised).

2. Social Negotiation (SN) during model development

In some cases agents stop the progress of the project implementation in order to face a certain issue using social negotiation. Since negotiation is a basic learning mechanism in a social constructivistic environment it is interesting to analyse the social negotiation episodes in order to estimate the learning quality of the involvement of agents. Special interest appears to the beginning and the ending modes of the SN episodes. SN analysis permits the estimation of the involvement style of each agent in terms of collaboration or competitive character.

3. *User Interface and Human Computer Interaction themes*

Despite the small frequency of these kind of episodes we consider them as a separate category because this infrequent appearance it is valuable software usability information in the context of MS evaluation.

c. The structure of the dialog during phase 2 (model exploitation).

During the phase 2 agents are mainly involved in social negotiations for the answer of activity sheet questions using the model. In these negotiations it is interesting to analyse the hypothesis formulation and verification by agents.

Collecting data from the dialogue analysis using the above framework it is possible to approach questions as the followings:

- What is the administration style of the project? Is the administration schema hierarchical-asymmetric or democratic-participative?
- What are the issues faced by SN? Who triggers the SN episodes? How do SN terminate? Are the conclusions always right? What is the learning quality of SN?
- Do students use the cognitive tools of MS during SN argumentations? In other words do students transform their thinking after the familiarization with MS?
- Is the UI a source of difficulty for students?

- Do agents evenly contribute to the SN? Are there patterns of students' participation style especially according to the collaboration or competition among the agents?

d. The hierarchical classification system for the messages

According to the previous proposed dialogue structure we defined the hierarchical classification system of the next table. In the followings we will apply the above described analysis framework to three typical activities implementations corresponding to the three modes of use. For each case we will present:

1. A general view of the interaction during the activity showing the duration (using quantum of 240 sec) and the contribution of each agent.
2. A pie chart showing the frequency distribution of chat (or oral where apply) messages in the main categories mentioned above. This distribution permits the general estimation of the collaboration quality.
3. A Bar chart showing the contribution of each agent to the previous distribution. With this chart we can estimate the participation and involvement level of each agent.
4. After the general analysis we proceed to the analysis of messages of categories 2. COLLABORATION DURING MODEL DEVELOPMENT, 3. SOCIAL NEGOTIATION DURING MODEL DEVELOPMENT, and 6. COLLABORATION DURING MODEL EXPLOITATION to their subcategories in general and per agent using proper pie and bar chart correspondingly.
5. A small characteristic dialogue episode from each case.

1. **SOCIAL CONVERSATION (IRRELEVANT TO THE PROJECT).** e.g. [Sir you are a thief], [Wait! Do you consider me, a wizard?]

2. **COLLABORATION DURING MODEL DEVELOPMENT**

2.1 **PLANNING.** e.g. [I will construct the model just like the previous activity, you watch me to detect any error.]

2.2 **SCHEDULING.** e.g. [Now I am going to construct the second company and after we are going to produce the diagram]

2.3 **ASSIGNMENT.** e.g. [set the values for the axes.]

2.4 **AUDITING.** e.g. [check if you have done all the steps you should.]

2.5 **UI AND/OR HCI ISSUES.** e.g. [Kiriakos, move the second model more to the left.]

3 SOCIAL NEGOTIATION DURING MODEL DEVELOPMENT

SN REQUEST BY QUESTION. e.g. [What max and min value I should set? They are not given. Should I use random values?]

SN REQUEST BY DISAGREEMENT. e.g. [You didn't set the right quantities to the axes]

STATEMENT/DECLARATION. e.g. [13E for the standard monthly cost and 0.03E for the cost per second]

REQUEST FOR EXPLANATION. e.g. [which company are you working on?] [How? I do not understand what you are asking.]

EXPLANATION. e.g. [That's why we should produce diagrams and table of values]

REQUEST FOR STATEMENT/DECLARATION VERIFICATION. e.g. [This should be as the one in the day before yesterday. Isn't it?] [Is it better now sir?]

VERIFICATION POSITIVE. e.g. [Very good]

VERIFICATION NEGATIVE. e.g. [No, the standard monthly cost and cost per second are constants]

REQUEST FOR VERIFICATION CLARIFICATION

3.10 VERIFICATION CLARIFICATION e.g. [I believe this because…]

3.11 COMPROMISE e.g. [we will set randomly.]

3.12 **AGREEMENT.** e.g. [Very good, Kiriakos. Let's proceed with the second company. Define again the entities.]

3.13 **REQUEST FOR CALL OF THIRD NEGOTIATOR.** e.g. [Neither do I. SOS, SOS!!! Sir, we do not know what values to set] [When you define it call Mrs Argiro to tell you what to do with axes ok?]

4 MOTIVATION. e.g. [quick.] [at last!]

5 COORDINATION. e.g. [Rodoula still has the key.] [Did you answer questions No 1 and 2?]

6 COLLABORATION DURING MODEL EXPLOITATION

6.01 HYPOTHESIS STATEMENT-PROPOSITION. e.g. [It is preferable the grater constant monthly cost with cheaper cost per second while if we speak much it not preferable the expensive cost per second, what do you think?]

6.02 REQUEST FOR HYPOTHESIS VERIFICATION. e.g. [Why is preferable the second company, rodoula?]

6.03 REQUEST FOR HYPOTHESIS-STATEMENT CLARIFICATION. e.g. [What value do you mean?]

6.04 **HYPOTHESIS-STATEMENT CLARIFICATION.** e.g. [That is if we speak for less for 303 seconds per month company A is preferable]

6.05 **VERIFICATION POSITIVE.** e.g. [correct!]

6.06 **VERIFICATION NEGATIVE.** e.g. [No, 900sec.]

6.07 **REQUEST FOR HYPOTHESIS-STATEMENT VERIFICATION CLARIFICATION.** e.g. [What are we going to note finally?]

6.08 **HYPOTHESIS-STATEMENT VERIFICATION CLARIFICATION.** e.g. [I believe 300 because until this time point someone pays less with company A than B.]

6.09 **MS REPRESENTATION TOOL USE PROPOSAL.** e.g. [lets produce a diagram], [See the table of values]

6.10 **COMPROMISE.** e.g. [Ok, we finished with question no 3, company B is preferable. Let's go to No 4. Think about it and then we talk about it.]

6.11 **AGREEMENT.** e.g. [Nice!] [ok]

6.12 **REQUEST FOR CALL OF THIRD NEGOTIATOR.** e.g. [Ask Mrs Argiro!!]

7 **UNCLASSIFIED.** e.g. [????][!!!!]

Table 15. The hierarchical dialog analysis system.

6.7.2.3.4 G.I?. 3.2 Case 1. Two students and one teacher collaborating through their own pc's (mode of use OME).

Project: Activity 3 – Mobile phone companies cost comparison.

Date: 19/1/2004

School: 5G.

a. General view of the collaborative action

In the following figure we can see the collaborative activity diagrams of the specified case. For an interpretation guide of collaborative action curve see G.II.1.a above.

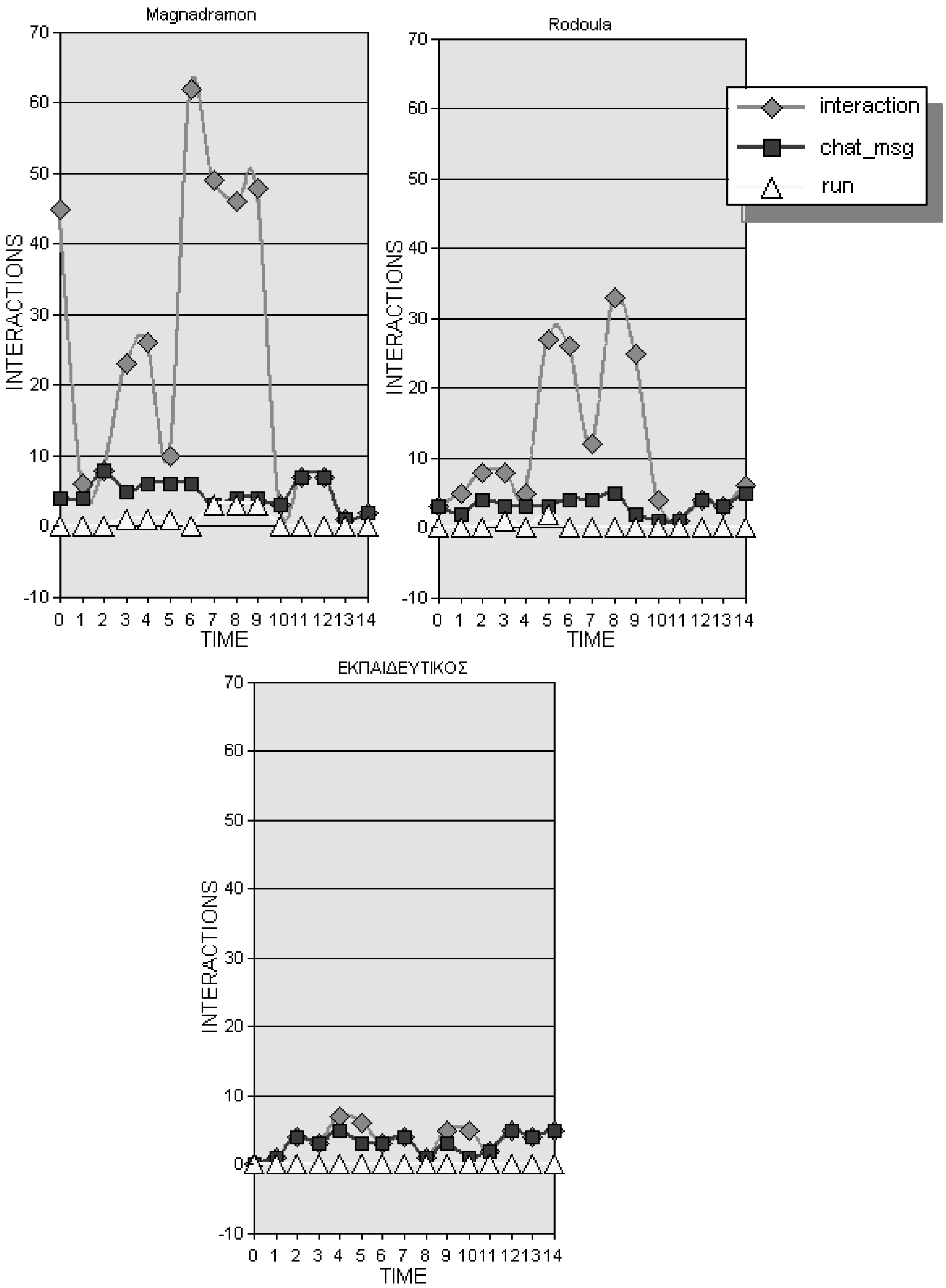


Figure 13. Collaboration activity curve for case 1.

Student Magnadramon tend to monopolize the activity using the mouse, despite his competitive style student rodoula manages to participate significantly during the 60 minutes of the activity. Teacher takes a rather discreet mediator and coaching role. Taking account of the fact that students answered all the activity sheet questions we can say that the above session was quite successful and useful for the team. More or less this is a typical collaboration diagram for mode of use OME that produced during study of University of Aegean.

b. Distribution of chat messages to the main categories

Observing the activity curves in the previous figure we see that agents are constantly chatting during collaboration. The distribution of these messages to the main categories of the analysis system of the Table 15 can give as idea about the quality of the learning experience of agents.

In next figure we can see that over 60% of the messages were about project management (22%), or negotiations for model exploitation (20%) or model development (20%). Another 30% percentage of messages concern the coordination between the agents. Coordination messages aim to construct and share knowledge common for all the agents about the state of the group. Only a small percentage (6%) of the messages was irrelevant to the problem solving activity. In other words agents in case 1 have been involved in a rather beneficial collaborative problem solving with many opportunities of social negotiation and high order thinking activation.

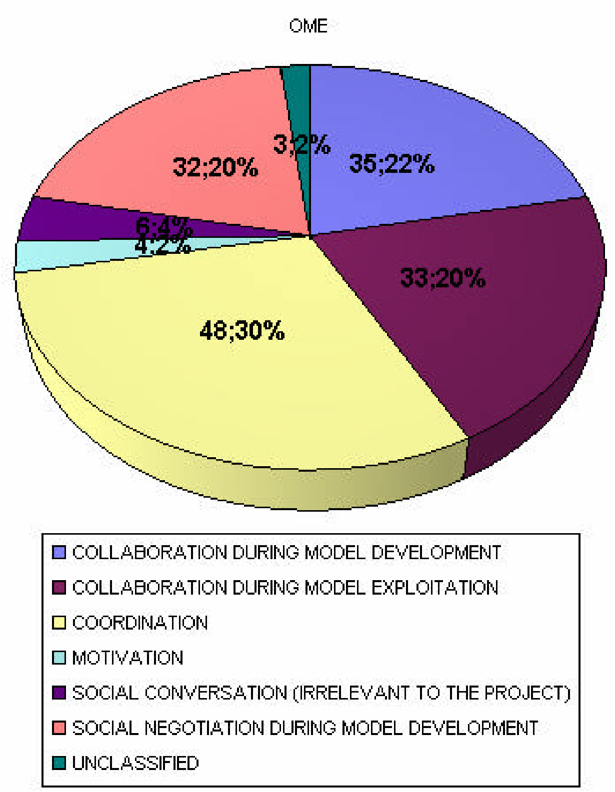


Figure 14. Chat message distribution to the main categories for case 1.

c. Distribution of chat messages to the main categories and agent.

After the previous figure observation, questions about each agent's contributions appear very interesting. In the following figure we can see the distribution of messages kinds to the agents. Agents appear to have an evenly distributed contribution to the categories of messages except the motivation and unclassified where students rodoula did not contribute at all.

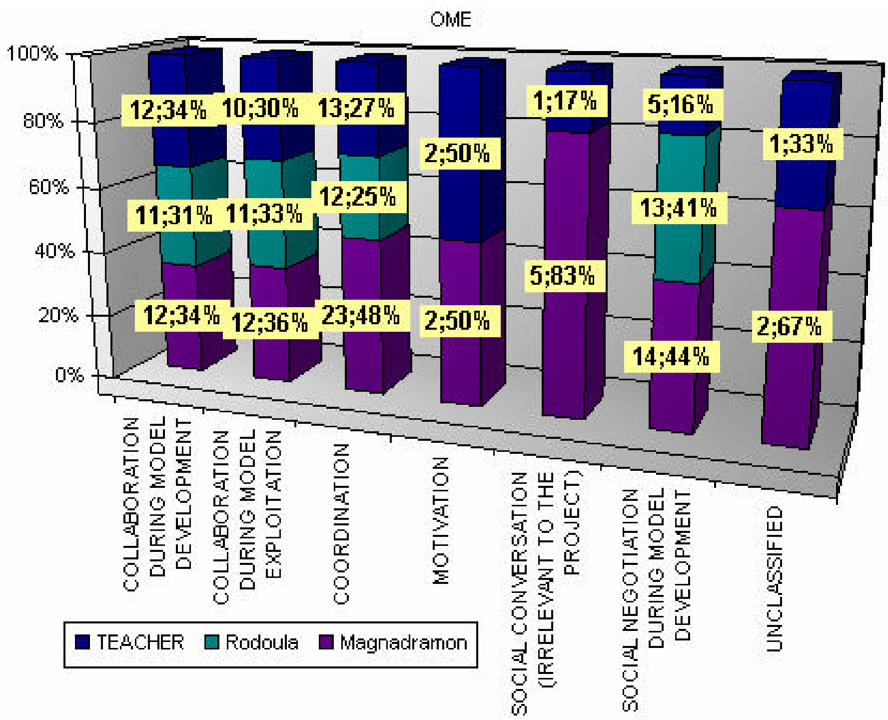


Figure 15. Distribution of messages to the main categories and agent for case 1.

d. Distribution of category 2 (COLLABORATION DURING MODEL DEVELOPMENT) messages to subcategories

In the next figure there is the distribution of category 2 messages to the corresponding subcategories. Category 2 subcategories give as information about the kind of project management that we had in the activity. As we can see we had a high percentage of auditing messages which as is going to be clear in the next section are from teacher.

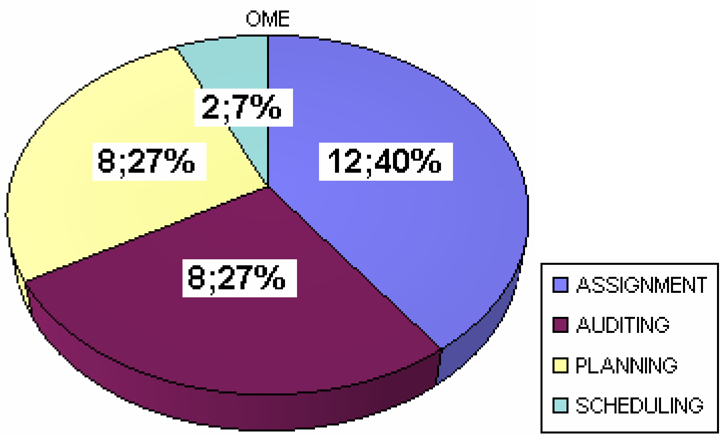


Figure 16. Distribution of category 2 messages for case 1.

e. Distribution of category 2 (COLLABORATION DURING MODEL DEVELOPMENT) messages to subcategories and agent

The distribution of category 2 messages to the agents gives as an idea about the management role of each agent and the management style for the whole activity. As it can bee seen in the next figure, teacher had a auditing and planning responsibility in the activity while magnadramon was mainly responsible for assignments and rodoula for planning. This fact in combination to the high percentage of the time that magnadramon (student kiriakos) was holding the key inform us that kiriakos was more or less competitive during the collabaration.

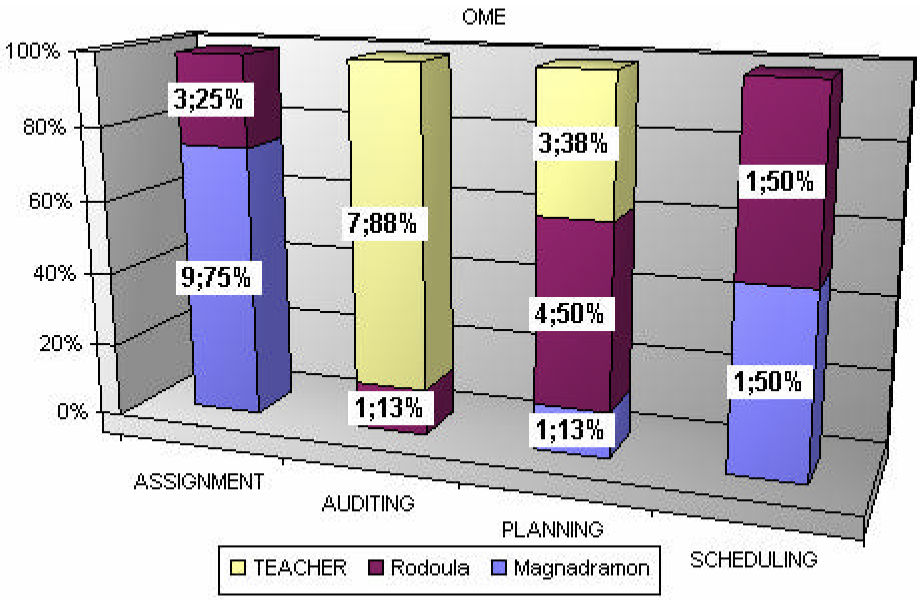


Figure 17. Distribution of category 2 messages to subcategories and agent for case 1.

Despite the fact Magnadramon adopted a rather managerial role in this case since decides the most of the assignments Rodoula has a significant contribution because she is evenly responsible for the planning. Teacher is a clear auditor in this case.

f. Distribution of category 3 (SOCIAL NEGOTIATION DURING MODEL DEVELOPMENT) messages to subcategories

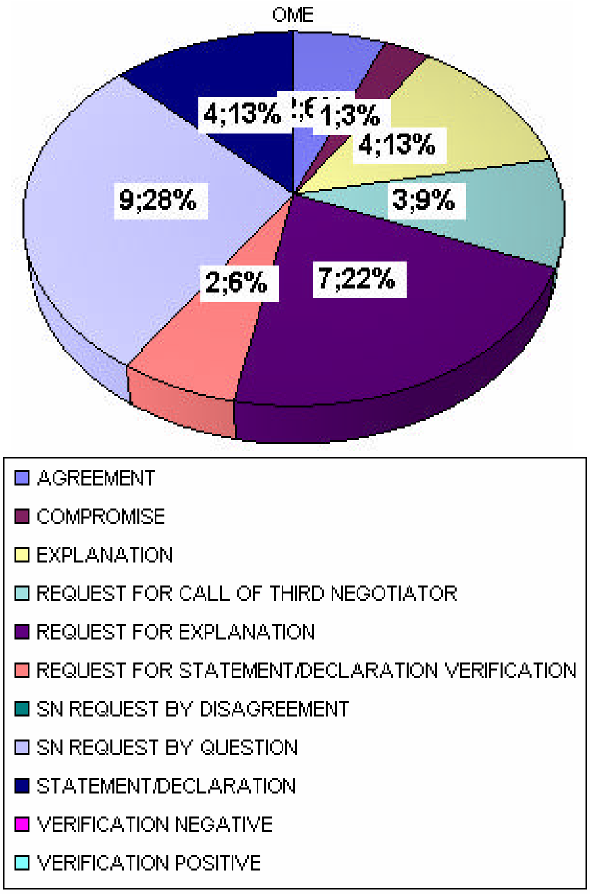


Figure 18. Distribution of category 3 messages to subcategories for case 1.

The above figure gives us the distribution of category 3 messages to the corresponding subcategories. This distribution gives us information about the quality of the dialogs when issues were negotiated during model development. We can see that there is a quite rich negotiation case with agreements, compromises, and even calls to third nego tiators (researcher).

g. Distribution of category 3 (SOCIAL NEGOTIATION DURING MODEL DEVELOPMENT) messages to subcategories and agent

For the estimation of the involvement of agents in the social negotiations during model development we can see the next figure. The distribution shows that teacher was restricted in request for explanations and questions. More specifically teacher adopts a coaching role facilitating the dialogue. The two students have rather equal contribution to the dialogue.

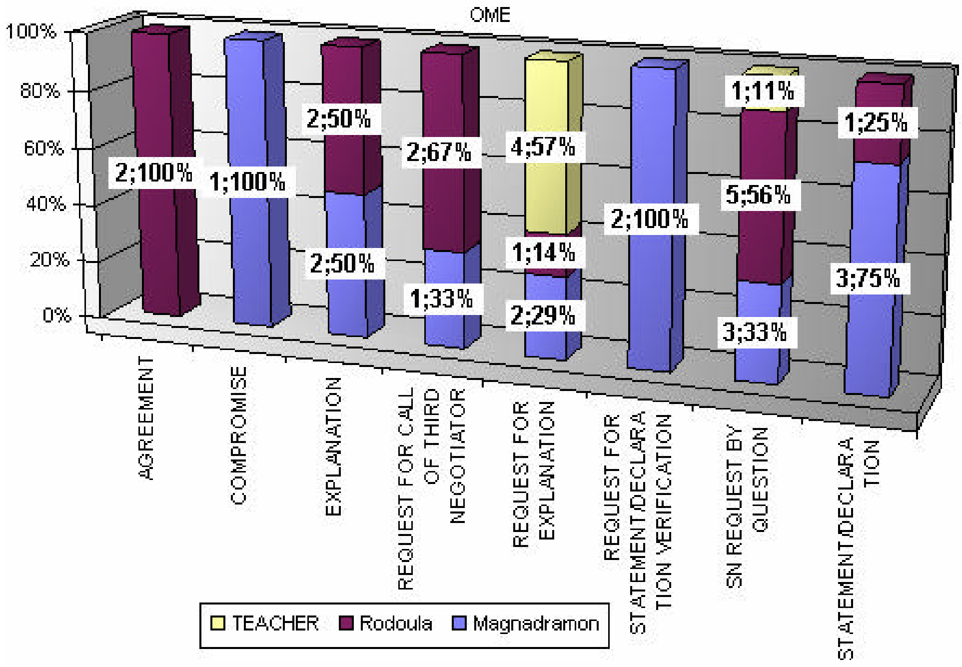


Figure 19. Distribution of category 3 messages to subcategories and agent for case 1.

h. Distribution of category 6 (COLLABORATION DURING MODEL EXPLOITATION) messages to subcategories

The quality of the involvement of students in social negotiation during problem solving can be estimated by the distribution of category 6 messages to the corresponding subcategories. We can see that there is a rich dialogue for the answer of activity sheet questions using the model. The agents formulate and test hypotheses and express logical reasoning and high order thinking using the ModellingSpace tools.

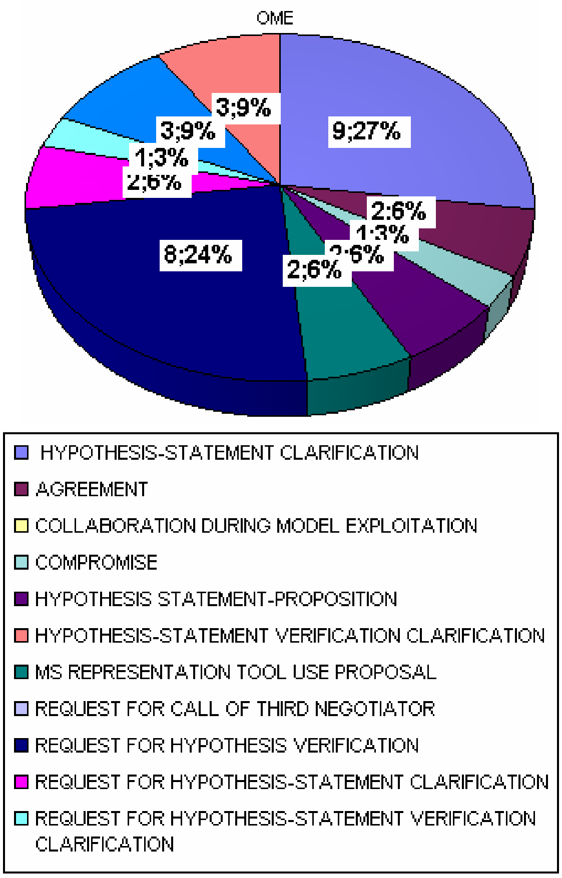


Figure 20. Distribution of category 6 messages to subcategories for case 1.

i. Distribution of category 6 (COLLABORATION DURING MODEL EXPLOITATION) messages to subcategories and agent

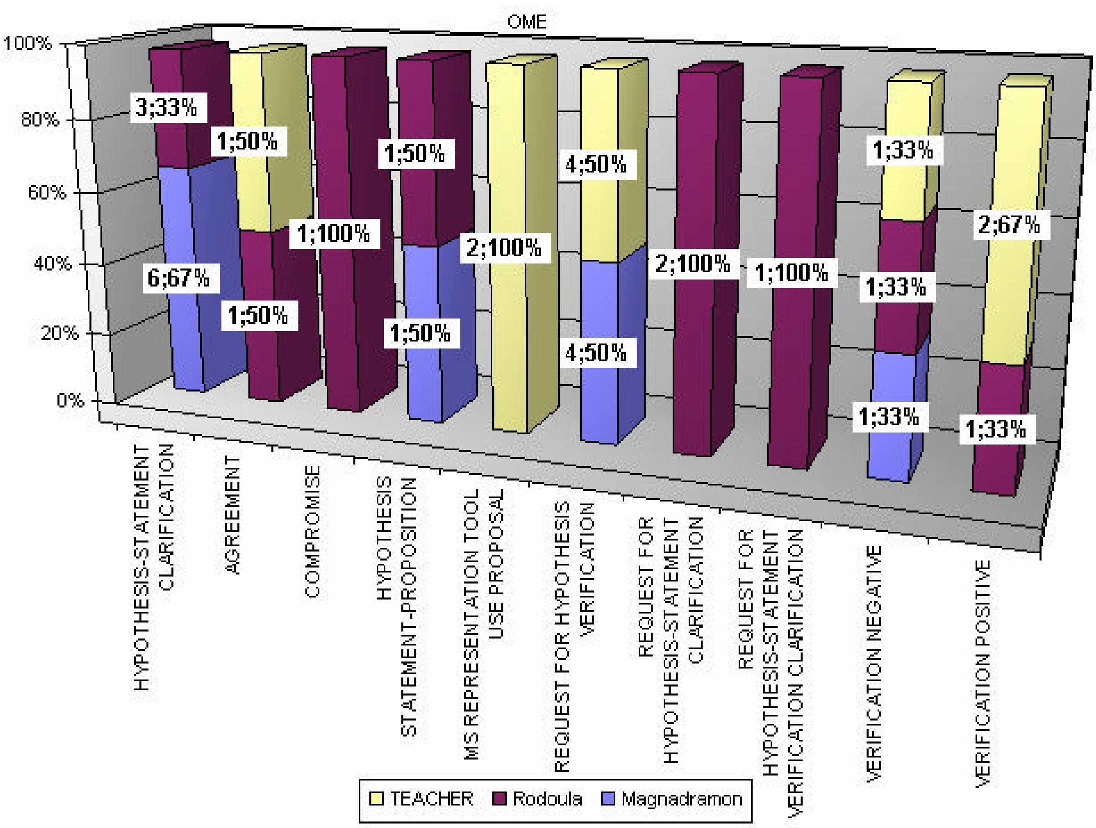


Figure 21. Distribution of category 6 messages to subcategories and agent for case 1.

The above bar chart supports the argument that students had a high quality learning experience rich of social negotiations. Teacher adopted the role of knowledge authority providing verifications. Student magnadramon seems to have the initiative in hypothesis formulation and to formulate competitive conditions than student rodoula which often express her agreement or compromise to magnadramon reasoning.

j. Dialogue episode from case 1

In order to get a more detailed view in the quality of dialogue during collaboration through MS we give the following sample.

AGENT	MESSAGE	CAT
Magnadramon	[We will see until which amount company A is preferable at value table.]	6.01
Teacher	[Nice!]	6.05
Rodoula	[What value do you mean?]	6.03
Magnadramon	[Wait, do you consider me a wizard?]	1
Magnadramon	[Just a minute.]	1
Magnadramon	[form the number 605 and before company A is preferable]	6.04
Magnadramon	[Ok?]	6.02

Teacher	[Did you answer questions no 1 and 2;]	5
Magnadramon	[That is if we speak less than 303 seconds per month company A is preferable.]	6.04
Magnadramon	[Not yet]	5
Teacher	[Correct!]	6.05
Magnadramon	[Ok Rodoula?]	6.02
Rodoula	[Yes lets go to question no 3]	6.11
Magnadramon	[on 303 seconds both companies cost the same.]	6.04
Magnadramon	[Lets go to question no 3?]	5
Teacher	[Very nice what do you think about 3?]	5
Rodoula	[Yes we must find at 90 seconds which company is cheaper.]	6.01
Magnadramon	[Company B is cheaper.]	6.06
Magnadramon	[Ok?]	6.02
Teacher	[900 seconds]	6.06
Rodoula	[Why B?]	6.03
Teacher	[Kiriakos, Rodoula is asking you something!]	4
Magnadramon	[Because, if 303 sec is about 5 minutes then for 15 minutes company B is cheaper.]	6.04
Magnadramon	[Did you understand?]	6.02
Rodoula	[No]	6.06
Teacher	[Why you do not use the model and the table of values?]	6.09
Magnadramon	[How much second are 15 minutes?]	6.04
Magnadramon	[Find it.]	6.04
Rodoula	[90?]	6.07
Teacher	[Why we have to work so hard o find it?]	1
Magnadramon	[Because we are idiots.]	1
Teacher	[Lets see the table of values for 900 seconds, what do you see?]	6.09
Rodoula	[Well, we finished question 3. Company B is cheaper. Let’s go to 4. Think about it and we talk]	6.10
Teacher	[Rodoula, why company B is cheaper?]	6.02
Rodoula	[I understood I saw the values]	6.04
Teacher	[What the numbers say?]	6.02
Rodoula	[That company B is costing 25E for 900 seconds while A 26.5 E]	6.04
Magnadramon	[yes]	5
Teacher	[I see 39,97 E for company A and 34E for company B?]	6.02
Teacher	[What do you think?]	6.02
Rodoula	[At 900seconds?]	5
Rodoula	[See you self!]	6.04
Teacher	[Yes for duration 900 seconds]	5
Rodoula	[You are right I was watching else where, company b I preferable again.]	6.05
Teacher	[Well done!]	6.11
Rodoula	[Ok?]	5
Magnadramon	[Rodoula I have a puzzle to finish are you going to be late?]	1

In the above sample students negotiate after the model development in order to answer the questions of activity sheet. From the dialogue we can see the competitive role of magnadramon (student kiriakos) as well the role of the teacher as a knowledge authority or collaboration facilitator.

k. Conclusions about case 1 (OME)

Students are able to collaborate and initiate despite the presence of the teacher. Students ask for the teacher to help them whenever they need so. Teacher need to adapt to a new role in which he/she facilitates the collaboration and the negotiation instead of providing the knowledge as the only authority. In any case it is obvious that there is a high quality learning collaboration in this group. This is a typical instance for the OME mode of use.

6.7.2.3.5 G.I?. 3.3 Case 2. Two students collaborating through their own pc's without teacher participation (mode of use OXE).

Project: Activity 3 – Mobile phone companies cost comparison.

Date: 19/1/2004

School: 5G.

a. General view of the collaborative action

In the following figure we can see the collaborative activity diagrams of the specified case. For an interpretation guide of collaborative action curve see G.II.1.a above.

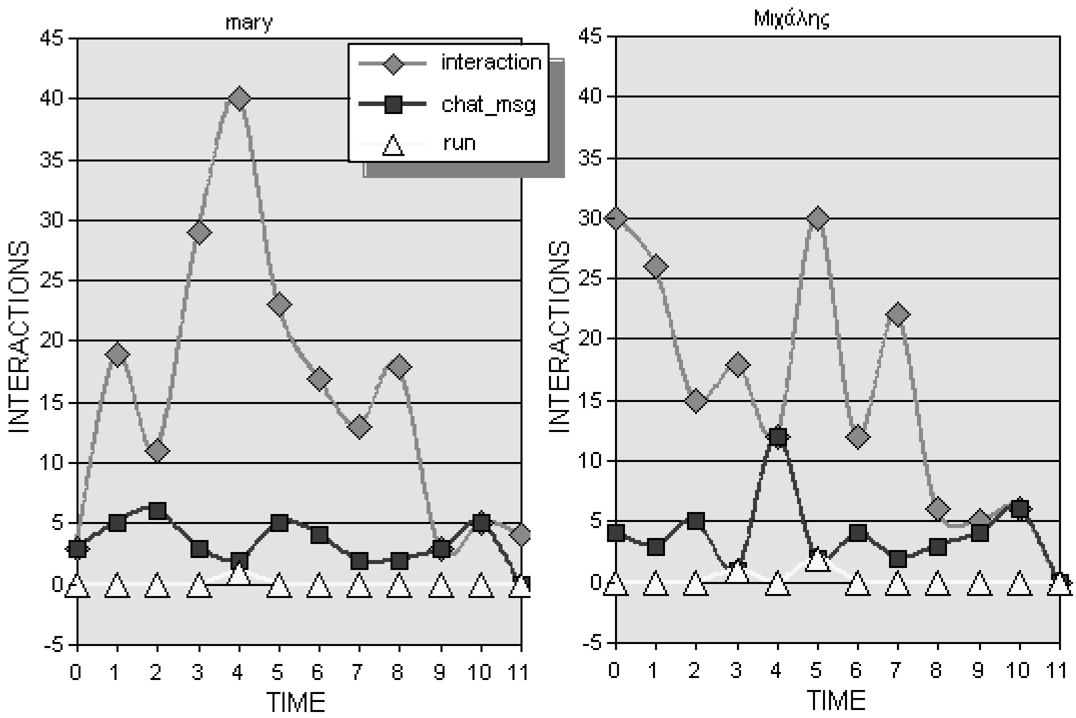


Figure 22. Collaboration activity curve for case 2.

Students despite the absence of any adult are actively involved in the collaborative problem solving using MS for about 45 minutes. Furthermore they evenly take the responsibility of mouse use from each other while they are constantly chatting. As in the previous case (OME) students are collaboratively develop the model and after they are mostly reflecting on it in order to answer the activity sheet questions. The reflection period begins after the quantum no 9 and is depicted by the approximation of interaction to chat_msg curve. . This is a case of real collaboration without competition among the group members.

b. Distribution of chat messages to the main categories

The distribution of these messages to the main categories of the analysis system of the Table 15 can give as idea about the quality of the learning experience of agents.

In next figure we can see that as in the previous case a big percentage (58%) of the messages were about project management (17%), or negotiations for model exploitation (26%) or model development (15%). Messages about coordination (20%) are quit less than in the previous case (30%) where we had 3 agents. Coordination messages aim to construct and share knowledge common for all the agents about the state of the group. A small percentage (3%) of the messages was irrelevant to the problem solving activity. The increased percentage (15%) of unclassified messages is due to repeated posting of question marks by the one agent when the other could not respond quickly enough. In general agents in case 2 have been involved in a high quality collaborative learning activity as in the case of OME despite the absence of adults' supervision. This fact is a stronger evidence for the motivation of students.

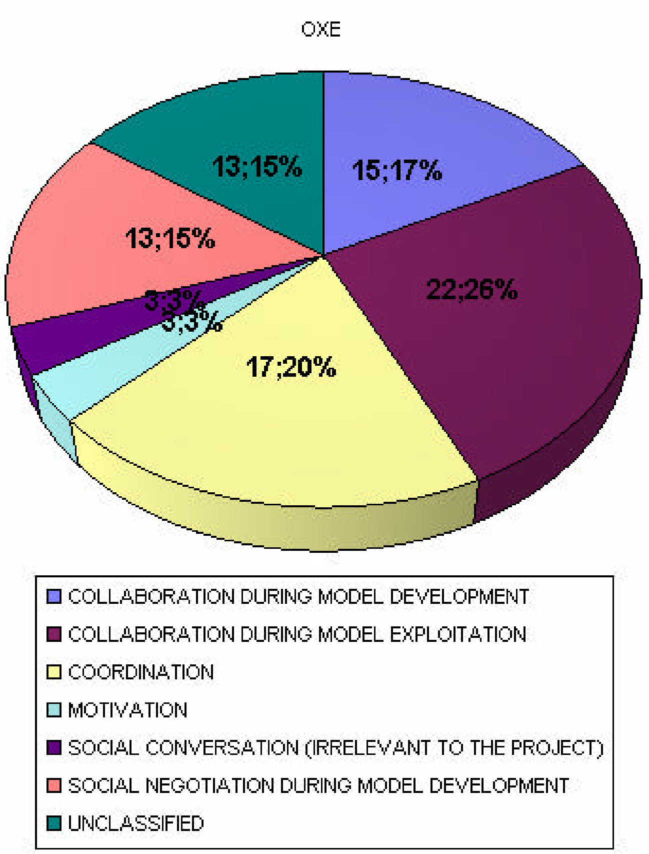


Figure 23. Chat message distribution to the main categories for case 2.

c. Distribution of chat messages to the main categories and agent.

In the following figure we can see the distribution of messages kinds to the agents so it is possible to estimate the agent contribution to the dialogue.

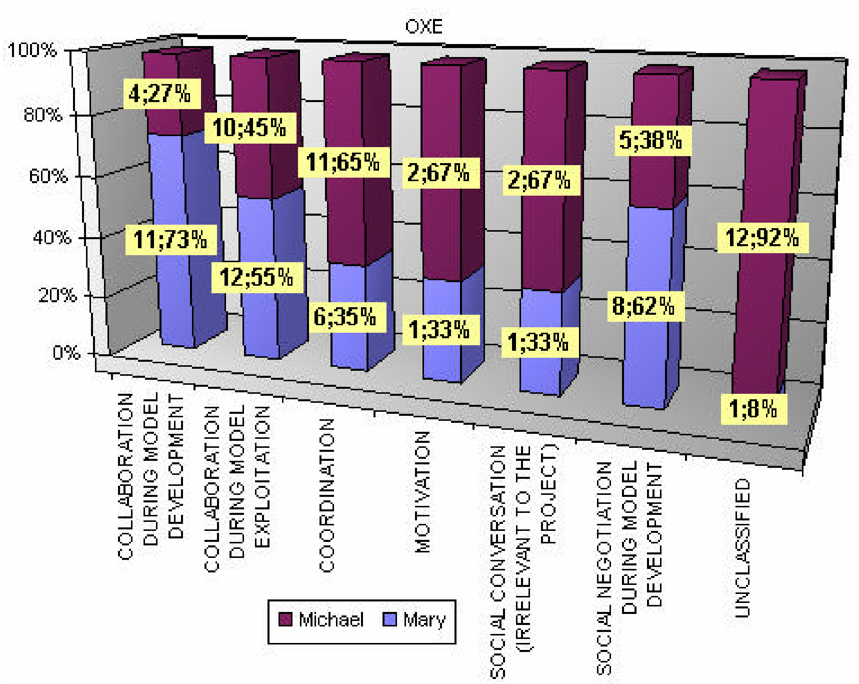


Figure 24. Distribution of messages to the main categories and agent for case 2.

In this case we have significant contributions from both the agents but mary adopted a rather managerial role as will be more clear in the followings (73% in contribution in collaboration during model development messages).

d. Distribution of category 2 (COLLABORATION DURING MODEL DEVELOPMENT) messages to subcategories

In the next figure there is the distribution of category 2 messages to the corresponding subcategories. Category 2 subcategories give as information about the kind of project management that we had in the activity. In contrast to the case 1 we have very low percentages of auditing and planning. Planning is indirectly implemented through assignment but auditing is rather a function that nobody is responsible or conscious of.

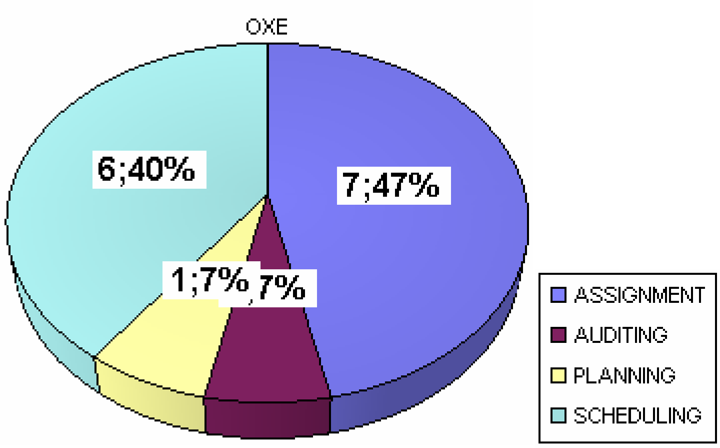


Figure 25. Distribution of category 2 messaged for case 2.

e. Distribution of category 2 (COLLABORATION DURING MODEL DEVELOPMENT) messages to subcategories and agent

Observing the following figure with the distribution of the category 2 messages to the agents we can estimate the managerial role and style of them. Mary's dominance is obvious. Mary is the main manager but Michael contributes in scheduling. There is not auditor and the planning is implemented through assignment.

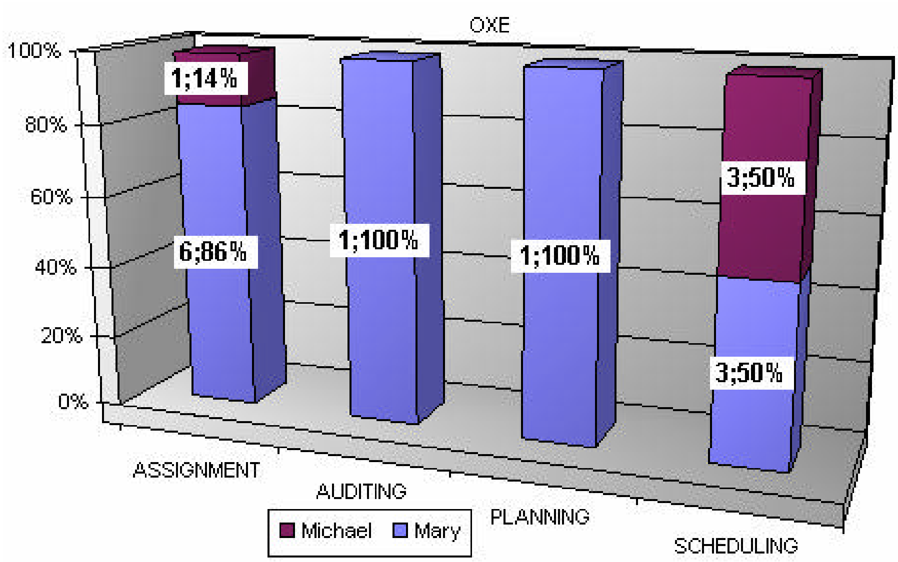


Figure 26. Distribution of category 2 messages to subcategories and agent for case 2.

f. Distribution of category 3 (SOCIAL NEGOTIATION DURING MODEL DEVELOPMENT) messages to subcategories

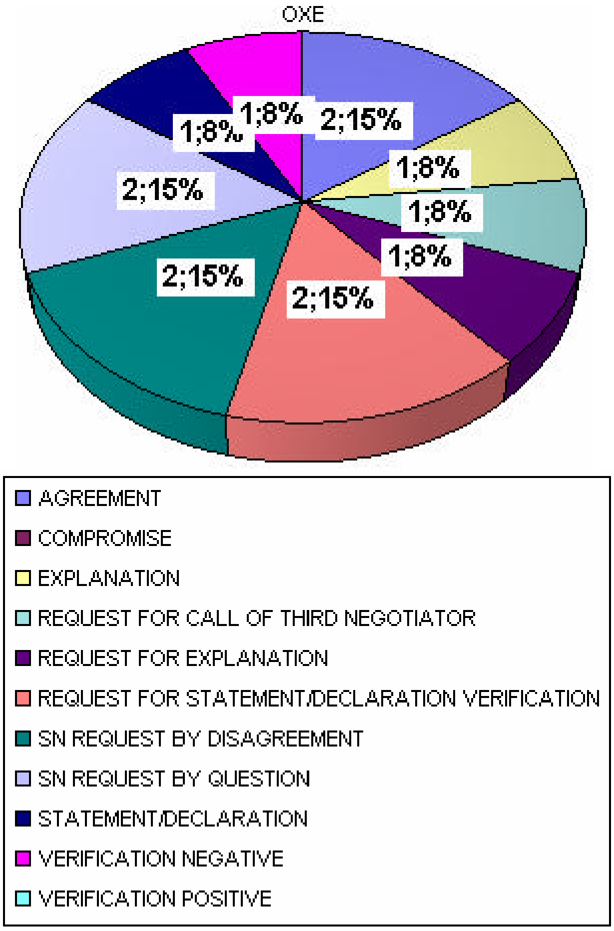


Figure 27. Distribution of category 3 messages to subcategories for case 2.

The above figure gives us the distribution of category 3 messages to the corresponding subcategories. This distribution gives us information about the quality of the dialogs when issues were negotiated during model development. The distribution is more or less like the one of case 1. Students are negotiating in order to face issues concluding to agreements, compromise, after a rich variety of message exchange.

g. Distribution of category 3 (SOCIAL NEGOTIATION DURING MODEL DEVELOPMENT) messages to subcategories and agent

For the estimation of the involvement of agents in the social negotiations during model development we can see the next figure. Mary had also a leading role in the dialogue but he had also to explain her thoughts to Michael.

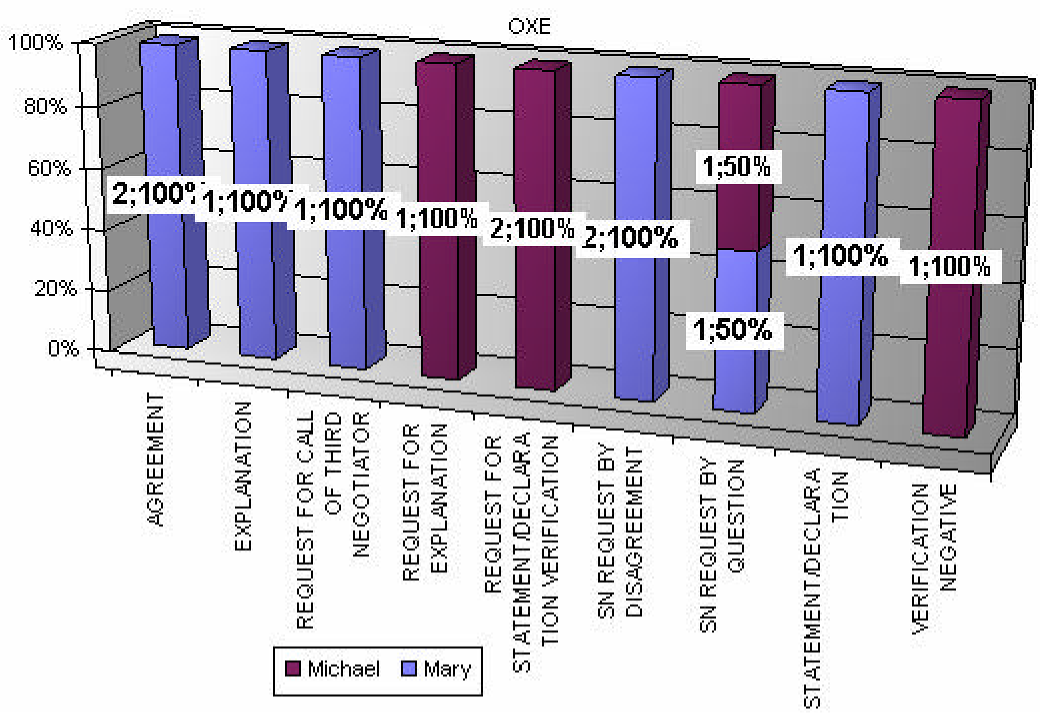


Figure 28. Distribution of category 3 messages to subcategories and agent for case 2.

h. Distribution of category 6 (COLLABORATION DURING MODEL EXPLOITATION) messages to subcategories

The quality of the involvement of students in social negotiation during problem solving can be estimated by the distribution of category 6 messages to the corresponding subcategories in the next figure. As in case 1 agents formulate and test hypotheses and express logical reasoning and high order thinking using the ModellingSpace tools.

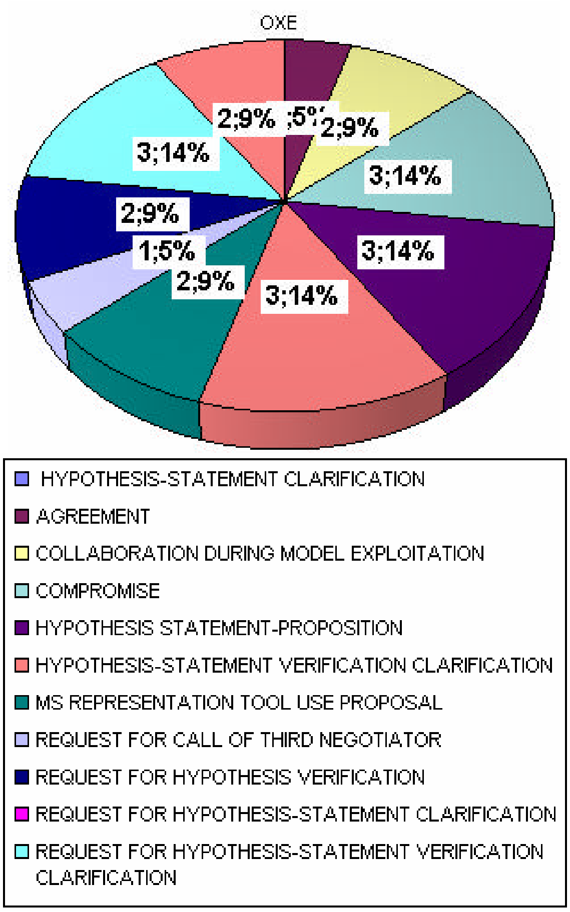


Figure 29. Distribution of category 6 messages to subcategories for case 2.

i. Distribution of category 6 (COLLABORATION DURING MODEL EXPLOITATION) messages to subcategories and agent

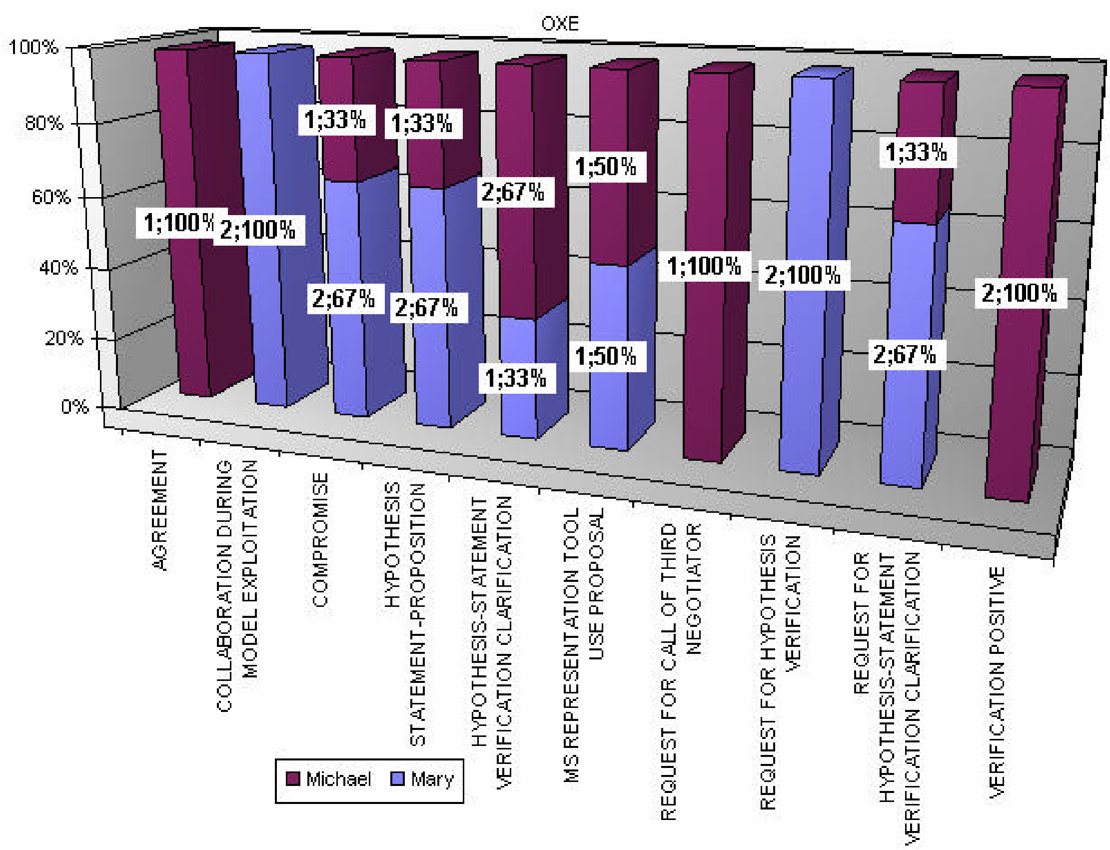


Figure 30. Distribution of category 6 messages to subcategories and agent for case 2.

Michael and Mary seem to have more or less similar contributions to the dialogue during model exploitation despite the managerial role of Mary during the development of the model. Even without the presence of adults students can engage in social negotiation for questions answering, the number of compromises is rather higher than that in cases 1 and 3.

j. Dialogue episode from case 2

In order to get a more detailed view in the quality of dialogue during collaboration through MS we give the following sample.

AGENT	MESSAGE	CAT
Mary	[Have you defined the relationship?]	5
Michael	[Something is going wrong!! Where do we must click first??]	3.01
Mary	[We must click first the independent, after the dependent and then the constants]	3.03
Michael	[Which quantities are these??]	3.04
Mary	[First is the standard monthly cost and then the duration and then the other two]	3.05

Michael	[The standard monthly cost with cost per second are constants]	3.08
Mary	[Yes, what did I said?]	3.12
Mary	[Are you going to define the relationship?]	5
Mary	[Define it correctly]	3.02
Michael	[Like this??]	3.06
Michael	[Now??]	3.06
Mary	[The arcs are correct]	3.12
Michael	[What is your problem??]	5
mary	[Bravo, at last !!!!!!!!!!!!!1]	4
mary	[Now run the model]	2.3

In the dialogue students negotiate during model development in order to define a relationship. Especially students are searching for the in depended variables in order to define the relationship. Students contribute complementary in order to solve the problem.

k. Conclusions about case 2 (OXE)

Despite the absence of adult's supervision students stay engaged in collaboration through ModellingSpace until they solve the activity sheet problems. This is a strong evidence of student's motivation. Students need guidance in order to develop auditing and planning project management abilities. Students are less competitive without adult's participation. Collaboration through ModellingSpace is a high quality learning experience as in case 1.

6.7.2.3.6 G.I?. 3.4 Case 3. Two groups of two students and one researcher each collaborating using one pc per group. (mode of use OMR).

Project: Activity 2 – Mobile phone call cost.

Date: 12/12/2003

School: TAP.

a. General view of the collaborative action

In the following figure we can see the collaborative activity diagrams of the specified case. For an interpretation guide of collaborative action curve see G.II.1.a above.

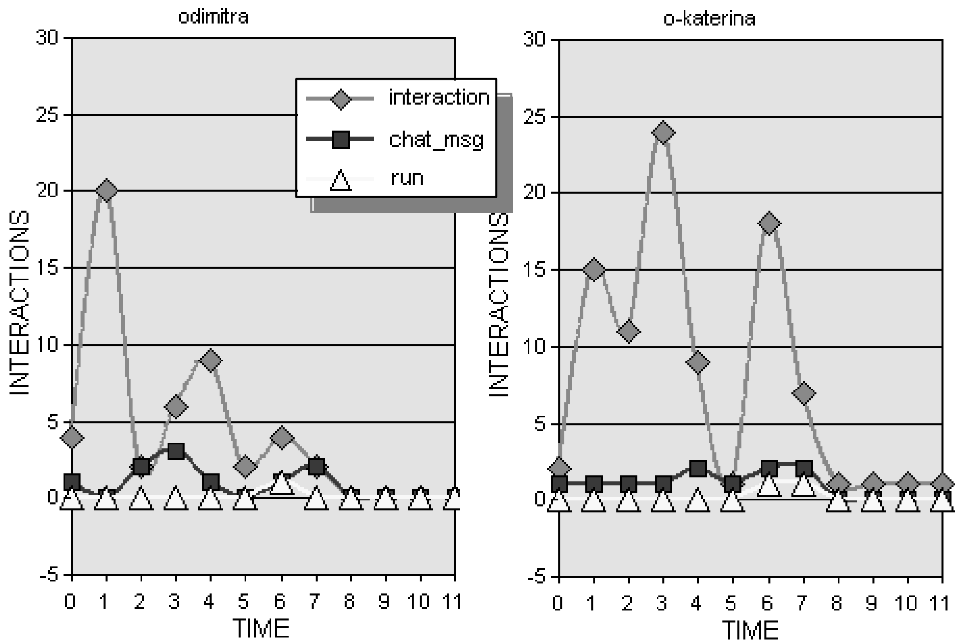


Figure 31. Collaboration activity curve for case 3.

As we can see the two groups are exchanging no more than the necessary chat messages during model development (before runs) and no one during the model exploitation phase. Students did not have a real collaboration but rather cooperation. In other words we have two separate groups cooperating rather collaborating.

b. Distribution of chat messages to the main categories

The distribution of these messages to the main categories of the analysis system of the Table 15 can give as idea about the quality of the learning experience of agents. The messages here are from the face to face dialogue between the students of the one group. In next figure we can see that as in the previous cases a big percentage (54%) of the messages were about project management (20%), or negotiations for model exploitation (10%) or model development (24%). Messages about coordination (14%) are less than in any of the previous because student can see each other. Another more significant deference to the other cases is that the useless messages are 31% percentage! Students find it very easy to speak and they waste a significant amount of the communication channel capacity to noisy and distracting messages. In general agents in case 3 are collaborating using much more messages per time unit but of much less quality. They spend only 10% in reflection while in the previous cases this percentage was about 20%.

In general students are motivated to use collaborate face to face using modeling space but the quality of the dialogues are rather lower quality than the previous cases.

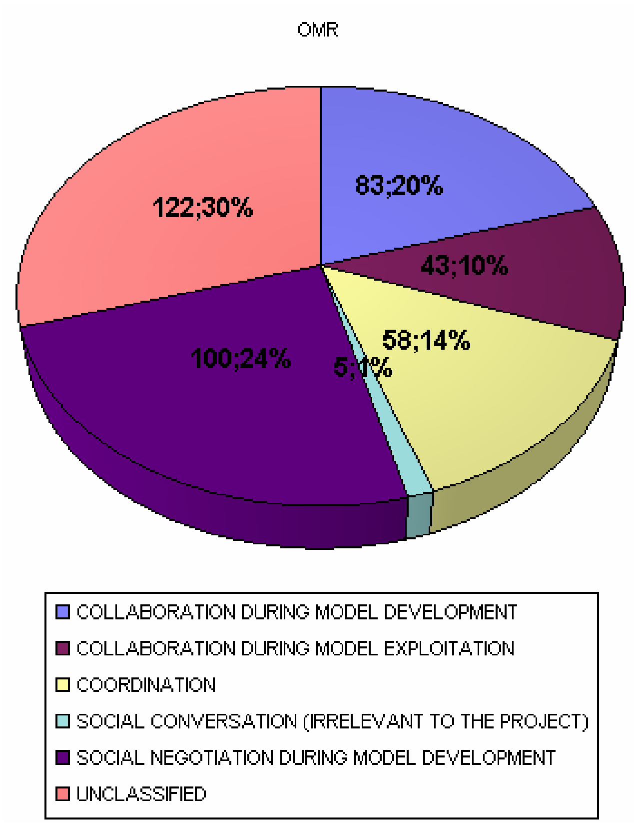


Figure 32. Chat message distribution to the main categories for case 3.

c. Distribution of chat messages to the main categories and agent.

In the following figure we can see the distribution of messages kinds to the agents so it is possible to estimate the agent contribution to the dialogue. Students' contribution is comparable. Figure shows that the researcher adopted a quit intervening role than that of the neutral observer. This is because of the traditional learning culture that the students are used of. Students gave to the researcher the typical role of the teacher. This is a quite significant reason for the difficulty to collaborate with the other students online.

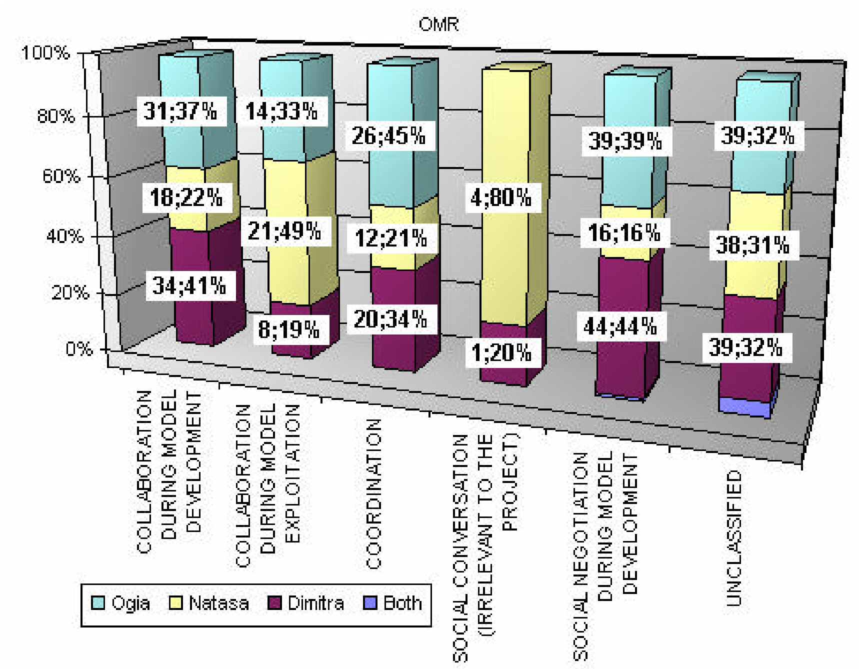


Figure 33. Distribution of messages to the main categories and agent for case 3.

d. Distribution of category 2 (COLLABORATION DURING MODEL DEVELOPMENT) messages to subcategories

In the next figure there is the distribution of category 2 messages to the corresponding subcategories. Category 2 subcategories give as information about the kind of project management that we had in the activity. As in the case 1 and in contrast to case 2 there is a high percentage of planning and auditing messages. As will be clear this is because of the adult presence.

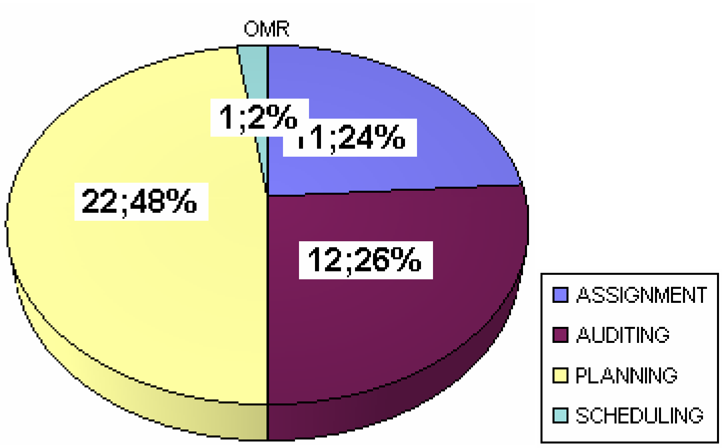


Figure 34. Distribution of category 2 messages for case 3.

e. Distribution of category 2 (COLLABORATION DURING MODEL DEVELOPMENT) messages to subcategories and agent

Observing the following figure with the distribution of the category 2 messages to the agents we can estimate the managerial role and style of them. It is clear that students are rather peer collaborators in project management with Ogia to be more responsible for the planning. The researcher Dimitra adopted the auditor role forcing the students to implement consciously planning in order to produce information for modeling process as been understood by the students.

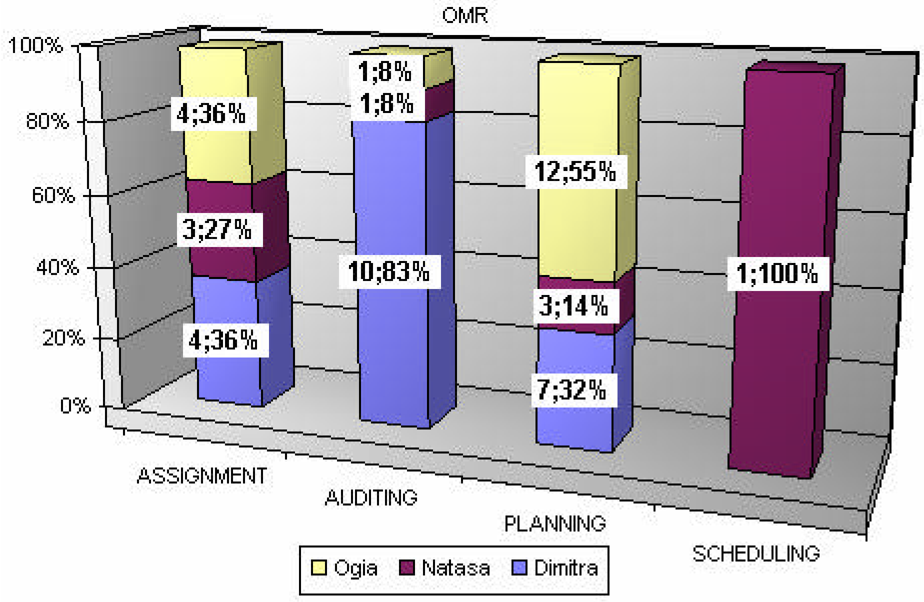


Figure 35. Distribution of category 2 messages to subcategories and agent for case 3.

f. Distribution of category 3 (SOCIAL NEGOTIATION DURING MODEL DEVELOPMENT) messages to subcategories

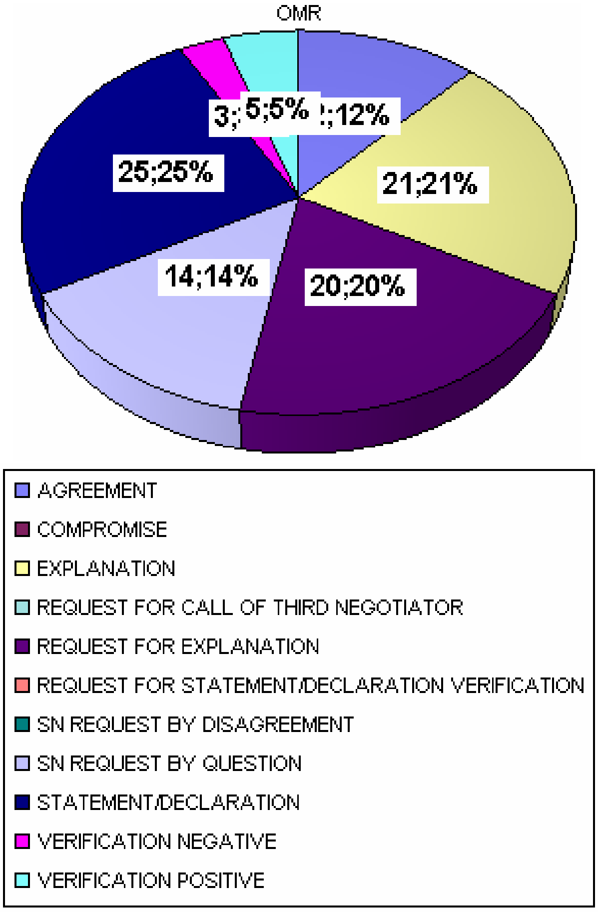


Figure 36. Distribution of category 3 messages to subcategories for case 3.

The above figure gives us the distribution of category 3 messages to the corresponding subcategories. This distribution gives us information about the quality of the dialogs when issues were negotiated during model development. The distribution is more or less like the one of cases 1 and 2. Students have rich and effective conversations during model development.

g. Distribution of category 3 (SOCIAL NEGOTIATION DURING MODEL DEVELOPMENT) messages to subcategories and agent

For the estimation of the involvement of agents in the social negotiations during model development we can see the next figure. In general Ogia seem to have more significant contribution to the dialogues. Natasa was watching carefully the logical reasoning of Ogia and preferred to find faults (negative verifications). It seems that researcher is asked to verify students reasoning and frequently she asks questions in order to facilitate the dialogue.

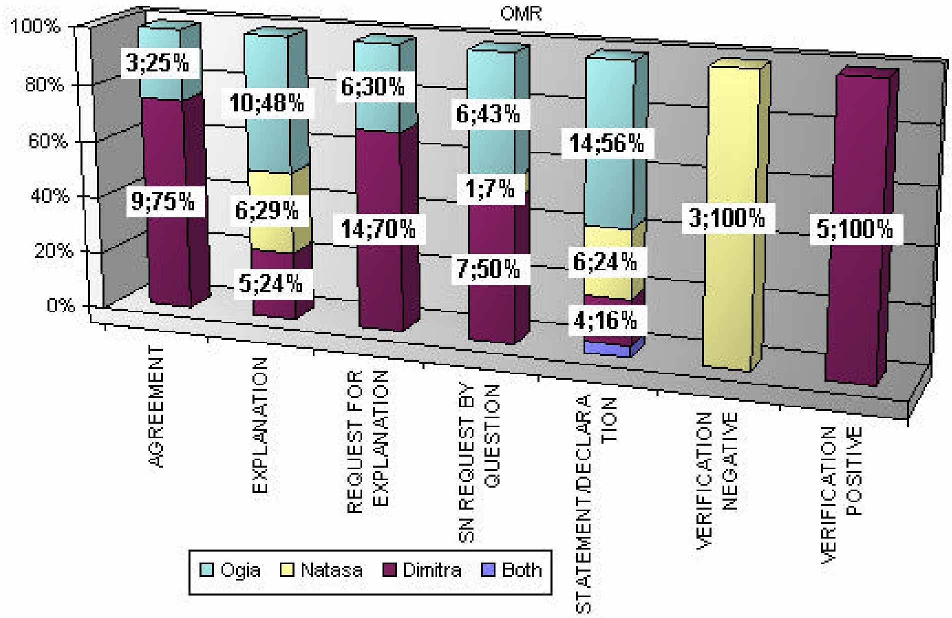


Figure 37. Distribution of category 3 messages to subcategories and agent for case 3.

Students ask from the researcher (Dimitra) to play the traditional teachers role as a knowledge authority, the positive verifications and agreement frequency by the researcher is consider strong evidence for this.

h. Distribution of category 6 (COLLABORATION DURING MODEL EXPLOITATION) messages to subcategories

The quality of the involvement of students in social negotiation during problem solving can be estimated by the distribution of category 6 messages to the corresponding subcategories in the next figure. As in cases 1 and 2, agents formulate and test hypotheses and express logical reasoning and high order thinking using the ModellingSpace tools.

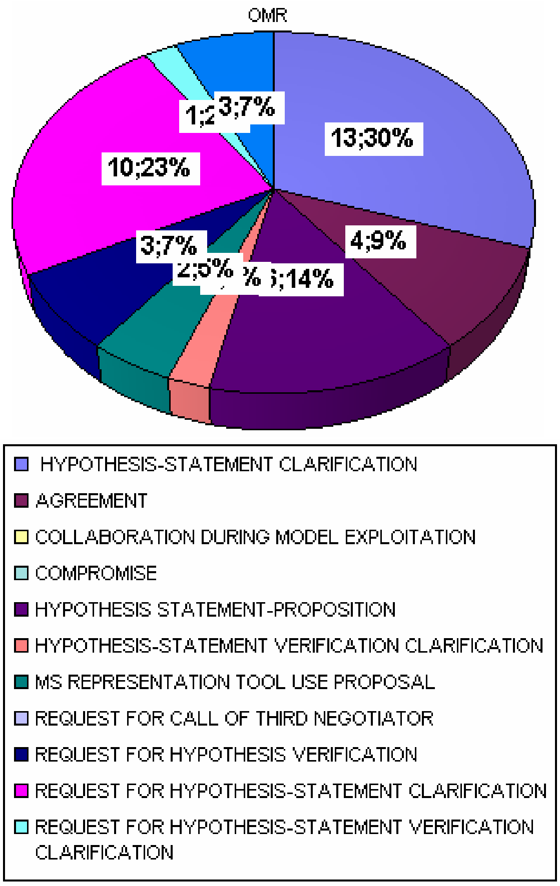


Figure 38. Distribution of category 6 messages to subcategories for case 3.

i. Distribution of category 6 (COLLABORATION DURING MODEL EXPLOITATION) messages to subcategories and agent

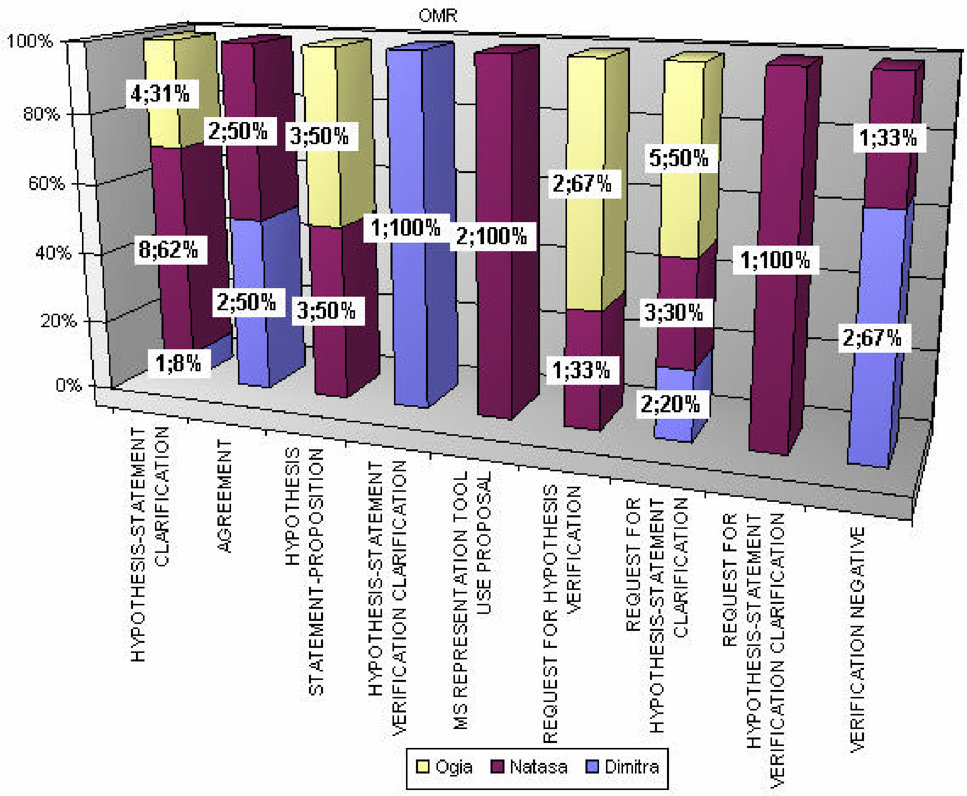


Figure 39. Distribution of category 6 messages to subcategories and agent for case 3.

Students contributed equally to hypothesis posting during model exploitation for questions answering. Student Natasa adopted a more critical role asking more frequently for hypothesis-statement clarifications than Ogia. The researcher Dimitra has been given a knowledge validator role by the students who asked for verification of their answers. Students again have been actively engaged in social negotiation using MS in order to answer the activity sheet questions.

j. Dialogue episode from case 3

In order to get a more detailed view in the quality of dialogue during collaboration through MS we give the sample in the following table. It is obvious that the main dialogue thread concerns Dimitra and Ogia while Natassa is watching carefully. It is also possible to observe the researcher guiding and auditing role. The episode is about an algebraic formula construction to express the cost of the phone call to its parameters.

AGENT	MESSAGE	CAT
Dimitra	What is the question asking you? How much is he going to pay?	3.01

Ogia	Yes.	3.12
Dimitra	What is this amount depends on?	3.01
Ogia	On the duration of the calls .	3.03
Dimitra	That is Euros are depended on the time?	3.04
Ogia	The duration of the call.	3.05
Dimitra	Yes	3.07
Ogia	And the standard monthly cost.	3.05
Natasa	No, on the time and the cost per second.	3.08
Dimitra	Yes, which is the operator that connects them?	3.4
Natasa	Multiplication.	3.05
Dimitra	Nice, that is ………..	3.04
Natasa	We will multiply the duration.	3.05
Dimitra	Yes.	3.07
Natasa	With the cost per second to find the monthly cost.	3.03
Dimitra	Very nice ……….	3.07
Ogia	And we well add the constant monthly cost.	3.03
Dimitra	Very nice, write this………..write the formula and describe it on your paper .	3.12

k. Conclusions about case 3 (OMR)

Despite the quite good use of ModellingSpace and the high motivation of the students the presence of the researcher and the possibility to have face to face communication results at lower quality collaboration in OMR mode. Students in front of a pc preferred face to face collaboration than to the subgroup in the other end of the line. In addition students gave to the researcher a typical teacher role as the performance evaluator and the knowledge authority and they decreased their possibilities to exploit real social negotiation.

G.II.4. Teachers' interventions and strategies during collocated collaborative scenarios

G.II.4.1 Introduction

Up to the present, most of the synchronous computer mediated collaborative problem-solving studies have concentrated on students' learning processes, pointing to the success with which it can be used to enhanced learning in educations settings (Constantino-Gonzalez & al. 2001,Wu, et al. 2002). The teachers' role has been much less often studied, and when it is, is mostly for experimental purposes (Lund & Baker, 1999) and not for exploring real school and class conditions.

G.II.4.2 Purpose of the research

The present research aims at exploring synchronous computer mediated collaborative problem solving in real school context, with collocated students, in every day practice.

- How valuable does this approach appear to schoolteachers?
- What kind of interventions do they make during on-line activity and what are the results of these interventions, concerning students' reaction?
- What kind of interventions do they make during off-line debriefing sessions?
- Which are their functional roles when working on each mode and what guidance strategies do they apply?

This research question, independently from the effectiveness of collaborative learning, aims at exploring how valuable this approach may be for teachers. It presents a case study, that took place in a real school environment, where all participants, teacher and students, are located in one classroom, working on different computers, with typical problem-solving activities, (usually students worked in groups of two in front of the same computer). They used MS that supports synchronous collaborative learning.
The working hypothesis underlying the present research is that teachers, (supported with specific tools), could develop new teaching strategies, without being imposed to change dramatically their practices immediately.

At the next paragraphs, firstly we analyze the word file from COPRET in order to find the functional roles each teacher adapted during the collaboration (on –the fly), the teaching strategies teachers adapted and which were students' actions as a result of these interventions. Secondly, we analyze the data from camera recording where teachers intervened one or more days later, after studying the file from COPRET with students' dialogues and actions and/or their own on-line interventions. Our purpose is again to find the functional roles each teacher adapted during this debriefing session and the teaching strategies he/she applied.

G.II.4.3. Experimental Conditions

The teaching-learning sessions have taken place into two schools. 5th Gymnasium of Rhodes (*K9)* and 2nd TEE of Rhodes *(K10).* There are two groups for each school corresponding to the OME and OXE modes of use (See section D. Context of study for modes of use and section B for information about the schools).

Neither teacher had previous experience with computer supported collaborative learning, but Teacher1 is a researcher and has worked on improving teaching through computer use. The teachers were not provided any initial instruction on collaborative learning and best practices. After the experimental sessions, an interview took place with each one separately. The teacher placed students into mixed ability groups. The members of each group worked on their own computers, which were not located in the immediate vicinity of the class. Before starting, the students had a short lesson (20 minutes) on how to use ModellingSpace.

Students worked on activity 2 (see section C) during two instructive hours (4 * 45 minutes) each class.

G.II.4.4. Analysis

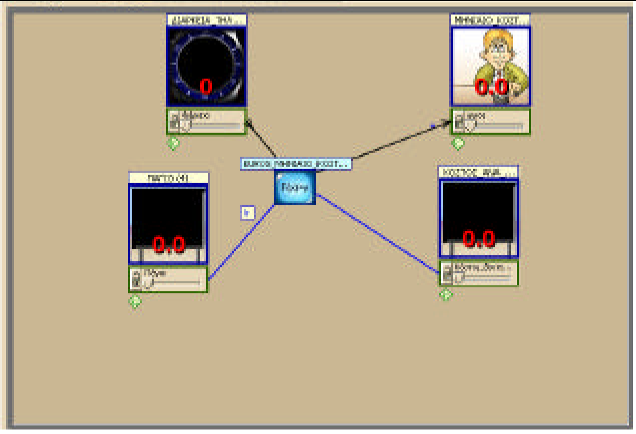
G.II.4.4.1. Analysis approach and research questions

Concerning the data, MS's log file was converted in a more readable print out form which contained:

1. Chat history between students and between students and teachers (data from log file),
2. Information about key's possession (data from log file),
3. Snapshots of the shared workspace after an action like Insertion, Modification or Deletion occurred (using log file the researcher localize the time points that such action occurred and using Playback Tool he captured the corresponding snapshots of the shared workspace).

As a result, a Word file was produced, respecting the chronological order of events, containing teacher's interventions (messages or actions) as well as students' dialogues and actions. This unified file served as the base for analysis for each team.

S29. [00:07:18][Rodoula: I can't insert the relationship, I would like some help. You can take the key and do it yourself, if you want.
S32. [00:07:26]Kyriakos : ok.
S33. [00:07:38]Teacher1 : Kyriako, please don't put pressure to Rodoula.
{Manager of Interaction, Teacher-requested intervention, conducting assessment on collaboration}.
[Kyriakos took the key and inserted the relationship, so the shared workspace is as follows]



S34. [00:08:16]Teacher1: Now explain Rodoula how you did it.

{*Manager of Interaction, Teacher-requested intervention, Assigns a role*}

Excerpt 1 (translated from original Greek).

The analysis is separated into the two great categories of *teachers' interventions*, according to the "moment of time" that they have taken place:

(1) *On-line interventions:* teacher's interventions during the lesson while they observe students' interactions (dialogues and actions at the common workspace).

(2) *Off-line interventions:* teacher's interventions, during the next course session, after studying the file of data provided to them by the researcher.

Usually, the teachers' interventions are studied, by assuming the intention of teachers messages or verbal expressions, attributing 'functional roles' (Vosniadou et al. 1999) or analyzing "question types and statement types" (Hmelo-Silver, 2002) that correspond to 'how teachers intervene' and lead to the discussion on the quality of teachers interventions, their strategies, and their approach. This kind of analysis seems to distinguish teachers' interventions from students' interactions, and often take place independently.

In the present study, we tried to analyze the way teachers intervened by assuming the specific functional role of each intervention and to assess their guidance activity.

Each intervention, given a specific cause, may include more than one message or verbal utterances by teachers. So, if during the conversation concerning a specific topic the teacher changes role, then we consider it as a new intervention. Referring to spoken dialogue during teachers' off-line interventions in a debriefing session, the unit of analysis was teachers' 'utterances'.

G.II.4.4.2. Analysis of On-Line Teachers' Interventions

G.II.4.4.2.1. Teachers' functional roles

Analysis of the data, word file from COPRET (Excerpt 1), revealed that the functional roles of teachers' interventions could be divided in four main categories. Teachers act as:

A)"providers of information related to the subject matter to be taught", B)"managers of interaction"

C)"managers of the task-process" and

D) "managers of the course process".

At next figure, the following information is presented: who has initialised the intervention, students (student-requested) or teachers (teacher-requested), if the intervention took place during making the model or afterwards, when students were using the model in order to answer the questions and the functional roles the teachers adapted. Figure 40 does not compare the teachers' interventions but it is mainly an overview of the later.

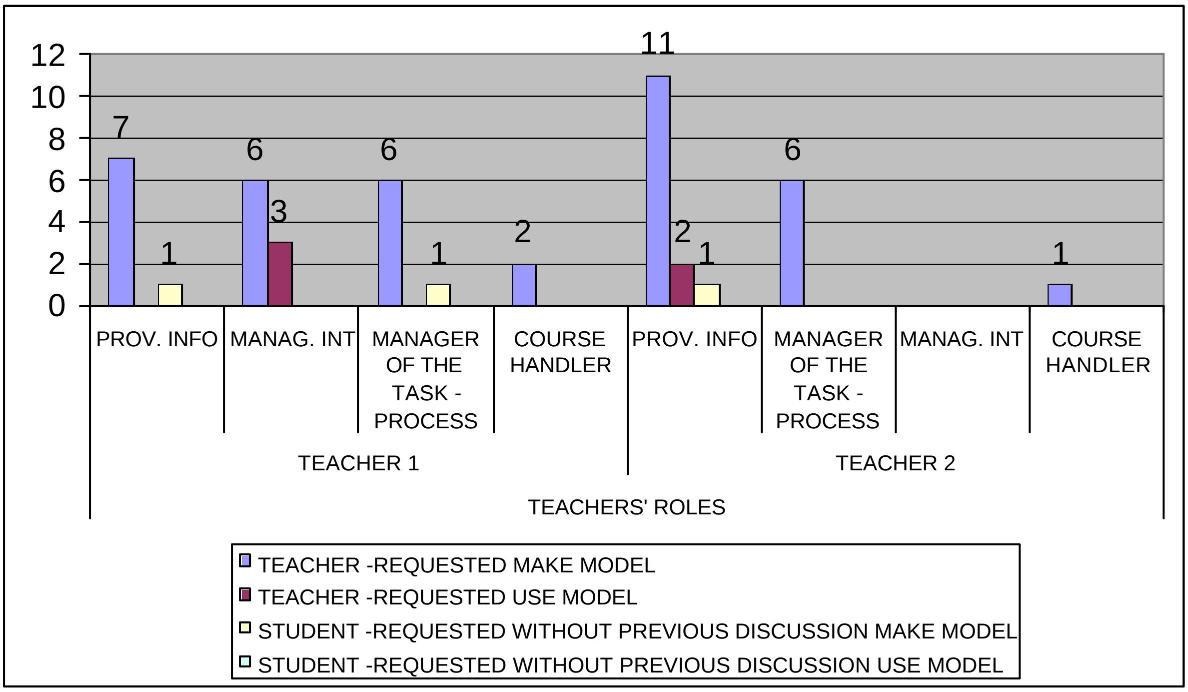


Figure 40. On-line teachers' roles.

As concluded from the above figure:

1. Both teachers mostly intervene by themselves, after analyzing students' actions and dialogues,

2. Teacher 2 acted mostly as provider of information concerning the subject matter to be taught during both phases of the task (make the model – use the model), while Teacher 1, who acted almost equally for the three roles, didn't act as provider of information during the phase where students use the model in order to answer the questions. Teacher2 explained during the interview, that he acted like this because *"that is how I was used to working until now, since I didn't have the possibility to become familiar with the processes where the students collaborate"*. Teacher1 said "*…students must*

at least make the model. This phase must be completed, so you must help them since we don't have unlimited time".

3. In cases of student-requested interventions, where students hadn't discuss the topic with the rest of the group, teachers shouldn't act as providers of information, as they did in two out of the three cases but as managers of the interaction, since they should encourage collaboration.

G.II.4.4.2.2. Teachers' guidance activity.

Each teacher's utterance has been assigned to a guidance activity having in mind the three main categories of intervention we have already defined.

Teacher's utterances belonging to Provider of Information are subdivided in two main categories:

1. Statements thereby which the teacher provided information to the students.
2. Questions asked by the teacher to the students, related to the subject matter to be taught.

The following Tables present teachers' guidance activities for each role.

Guidance activities of teacher's statements related to the subject matter to be taught		
Guidance activities	**Definition**	**Examples**
Explains	We put in this category all the cases in which the teacher explains a situation or a concept.	"You can't do a graph unless you have define the relationship"
Clarifies	Clarifies something previously said by himself or by a student. In a semantical level is very close to f.r. "Explains".	
Expose Scientific Knowledge	The teacher exposes scientific knowledges. We distinguish between: -explains or interpretates something in the appropriate terms -he exposes the definition of a concept or a law.	
Gives a hint	The teacher gives a low level indication in order to help the student(s) to find the answer.	"I think you should check the relationship"
Providing indications	The teacher points what they must do next, in order to continue. The indications is not a low level one.	"You should lock the constants."
Approves/Disapproves	The teacher approves or disapproves explicitly the 'opinion' or the 'action' of the student(s).	"Yea, that's right."
Summarizing	The teacher makes summaries or reviews of the discourse.	"So, we first put the entities, give prices and then insert the relationship."
Restating	The teacher restates what a student has said	

Reformulate students' comments	The teacher reformulates the students' speeches.	
Rhetorical comments		
Verify understanding	Generally it is a speech act addressed to the student(s) with the purpose to verify if the student have understand what was previously said.	

Table 16. Guidance activities of teacher's statements related to the subject matter to be taught 0n-line.

Guidance activities of teacher's questions related to the subject matter to be taught		
Guidance activities	**Definition**	**Examples**
Ask student to explain	The teacher ask student(s) to explain something, such as: -indicate a cause -justify something	"Why you open the graph window before define the relationship;"
Ask student to clarify	The questions asked after an initial question of explanation demanding to clarify the initial explanation.	
Ask student if he knows	When the question concerns a specific scientific knowledge which had been taught by the teacher in a previous lesson or in the current one.	
Ask student to examine the Validity of Explanation	Teacher questions asked after an initial question of explanation and after the explanation given by the student. The teacher not intervenes to disapproves directly the student's explanation but he gives him a counter example in order to help student to re-examine the validity of his own explanation.	
Ask student to approves/disapproves	When the question asked by the teacher: -contains the answer and the student has to tell if he agree or disagree with this (Yes, No) -contains two opposite answers and the student has to choice between them. In a semantical level, the answer can be of the same order as explanation.	
Ask student if they want help	When the teacher asks directly the students if they want to help them	

Table 17. Guidance activities of teacher's questions related to the subject matter to be taught on-line

Teacher's guidance activities as a manager of interaction.		
Guidance activities	**Definition**	**Examples**
Inviting students participation	The teacher invites the student(s) to participate	
Encourage collaboration	The teacher encourage the participants to collaborate	
Assigns a role	The teacher ask the student to do something in order to help the rest of the group: -to explain something to the rest of the team -to express loudly a hesitation, so everybody in the classroom can hear.	"Kyriako explain to Rodoula what you did"
Conducting assessment	The teacher makes references to students' contribution	"You did it great.'
Group formation		
Motivational comment		

Table 18. Teacher's guidance activities as a manager of interaction on-line.

Teacher's guidance activities as a manager of the task		
Guidance activities	**Definition**	**Examples**
Planning		"Next you should insert and define the relationship"
Monitoring group dynamics	The teacher checks on progress and request for planning.	"Kyriako is your model running;"
Assignment	The teacher ask the student(s) to do something.	"Katsouraki, make a graph"
Scheduling		

Table 19. Teacher's Guidance activities as manager of the task.

As far as teachers' interventions as managers of the course process are concerned, the reason of intervention had not to do with the specific solution or dialogue of groups, so they are not reported by the figure, given their minor importance.

So, teachers' messages are re-analyzed in order to assess their guidance activity. In analyzing these interventions special attention was paid to capturing the interaction between teacher and students rather on focusing on the syntactic/grammatical content.

A guidance activity reports the purpose of an utterance from the point of view of its speaker. It is attributed by the analyst as an interpretation of the speaker's intention in communication. Each teacher's utterance has been assigned to a guidance activity and are divided having in mind the three main categories of intervention we have already defined.

As a result we got the following figure:

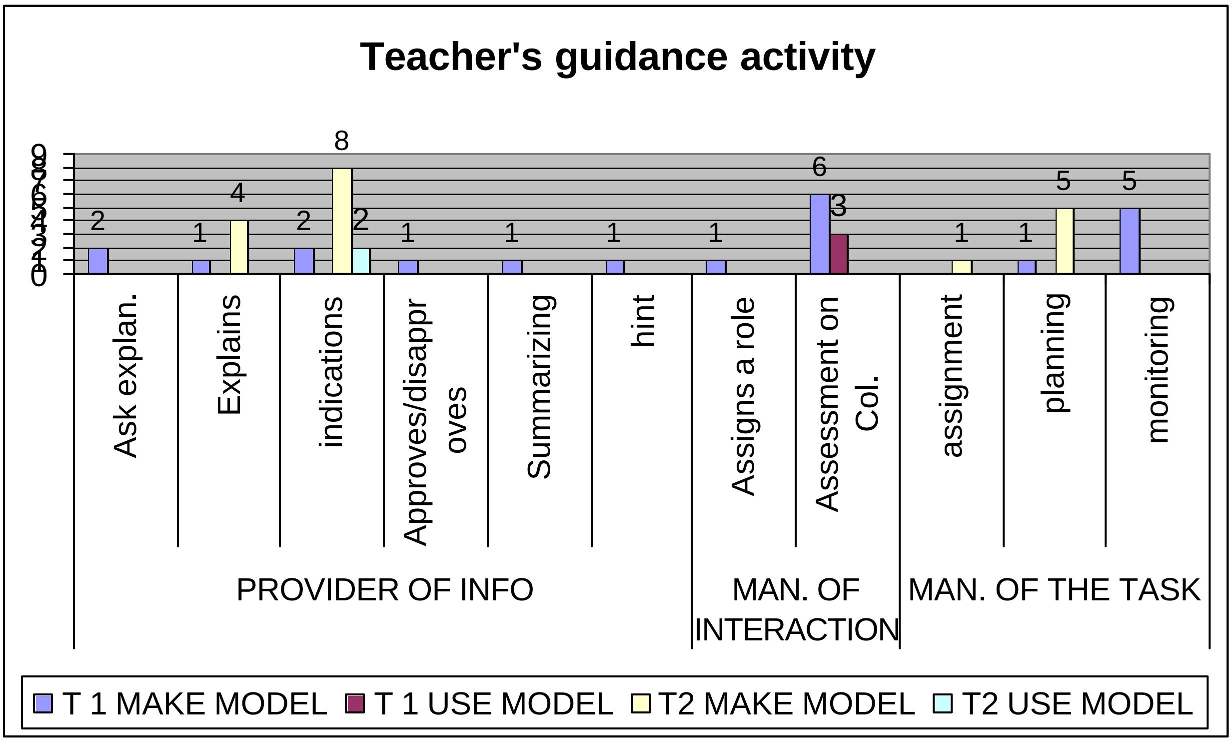


Figure 41: Teachers' on-line guidance activity.

As we can conclude, Teacher 2, not only acted mostly as Provider of Information but he was dominating during all phases of the activity. He did only explanations, indications, planning and assignment. He left nothing for the students.

On the other hand, Teacher 1 even when he acted as Provider of Information he asked for explanations and he gave hints. This means that he didn't give the information directly. Also, he acted as manager of Interaction, something that the Teacher 2 didn't at all, while as Manager of the Task, he did more monitoring, unlike Teacher 2 who did only planning (except one case that he did assignment).

G.II.4.4.2.3. Students' actions as a consequence of Teachers' interventions

Teachers' interventions, most of the times, influence students' behavior. Figure 40 presents students' action that follows a teacher's intervention. We grouped students' actions to ***Collaborative Learning Skills*** and to ***Non collaborative Learning Skills***.

Collaborative Learning Skills (Table 20) illustrates the conversation skills most often exhibited during effective collaborative learning and problem solving (Soller, et al., 1996). Non Collaborative Learning Skills include all the rest of students' actions.

Active Learning	Request	Ask for help/advice in solving the problem, or in understanding a team-mates comment.
	Inform	Direct or advance the conversation by providing information or advice.
	Motivate	Provide positive feedback and reinforcement.
Conversation	Task	Shift the current focus of the group to a new subtask or tool.
	Maintenance	Support group cohesion and peer involvement.
	Acknowledge	Inform peers that you read and/or appreciate their comments. Answer yes/no questions.
Creative Conflict	Argue	Reason (positively or negatively) about comments or suggestions made by team members.
	Mediate	Recommend an instructor intervene to answer a question.

Table 20. Definitions of Collaborative Learning Skills

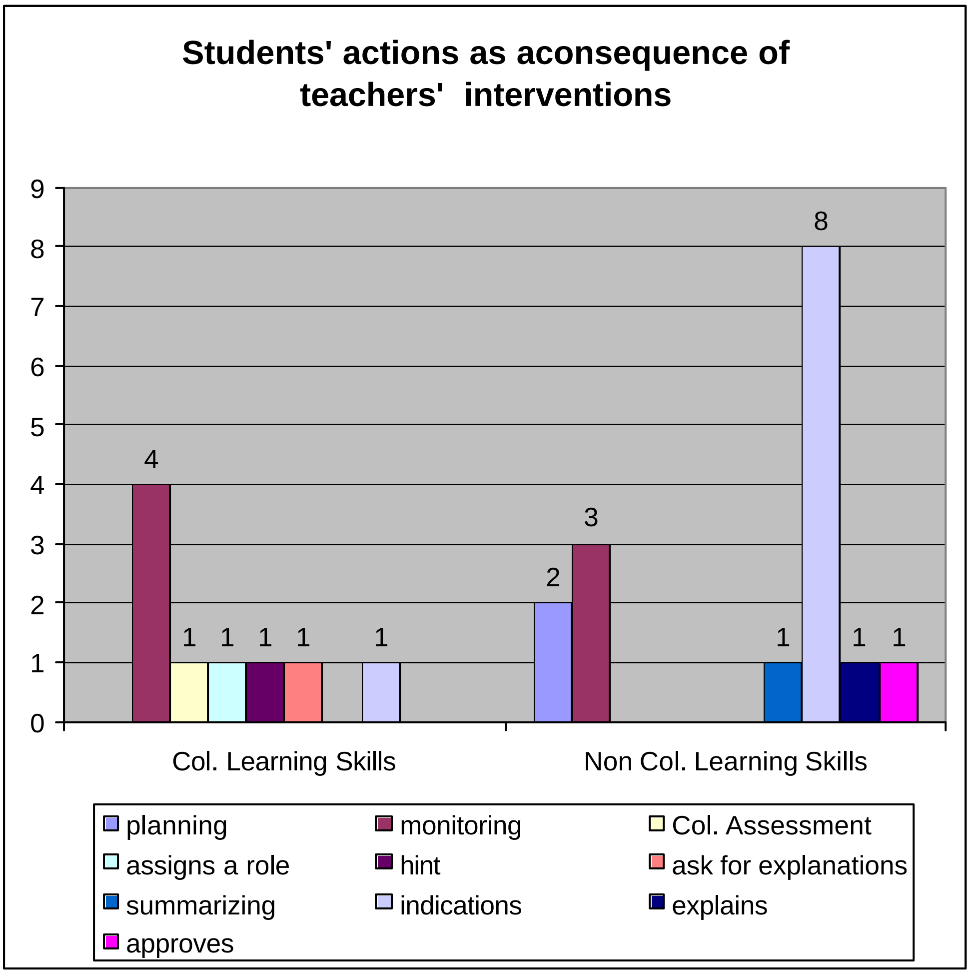


Figure 42. Students' actions as a consequence of Teachers' interventions

As we can conclude, when teachers intervene in order to give instructions or information, students don't develop Collaborative Learning Skills, they just follow teacher's instructions, or accept the information without any doubts.

G.II.4.4.3. Analysis of Off-line Teachers' interventions

After studying the file with teacher's on-line interventions and students' dialogues and actions, the teacher intervened one or more days later. In order to analyse the teachers off-line interventions, we focus again on the motive of each teacher's intervention, analysing this time the data from camera recording that was registering teachers' interventions to the two groups that were analysed during the previous paragraphs.

Analyses of the data revealed that the teachers adopt three different roles: A)"providers of information related to the subject matter to be taught", B)"commentator of collaboration that took place" and C)"commentator of students' knowledge concerning the subject matter to be taught.

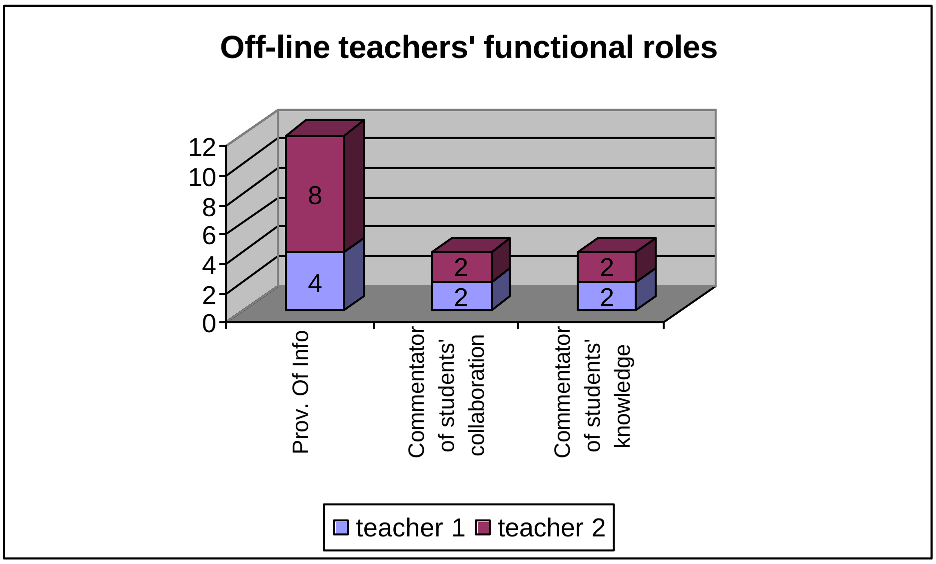


Figure 43. Off-line teachers' functional roles.

The following Tables and Figures present teachers' strategies for each role.

Teachers' strategies as Prov. Of Information during the debriefing session.		
Strategies	**Description**	**Examples**
Give instructions	When the teacher points to specific steps that must be done in order to solve problems like the one we had.	"The steps in order to make the model…."
Give explanations	We put in this category all the cases in which the teacher explains a situation or a concept	"There are constants and variables. The constants are those that…"
Correct misconceptions	We put in this category all the cases in which the teacher diagnoses a misconception from dialogues or actions, and tries to correct it.	"I think you couldn't proceed because you hadn't understood how to convert…"

Table 21. Teachers' strategies as Prov. Of Information during the debriefing session.

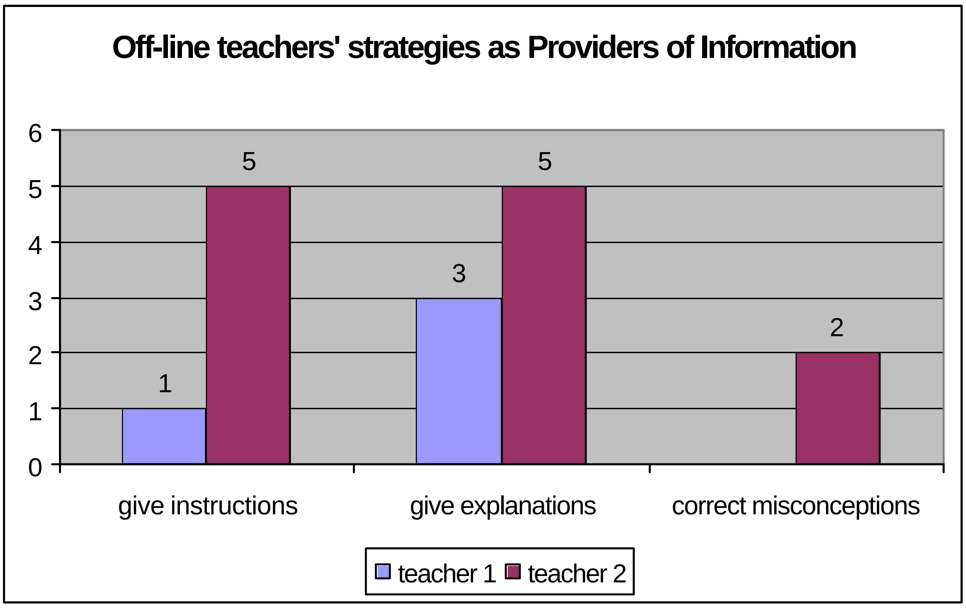


Figure 44. Teachers' strategies as Prov. Of Information during the debriefing session

Teachers' strategies as Commentator of students' collaboration during the debriefing session		
Stratégies	**Description**	**Examples**
Assess collaboration	Teacher assess students' collaboration	"I expected more from Athina"
Give instruction	Teacher gives instructions in order students to have effective collaboration	"It is important to explain my actions to my partners"

Table 22. Teachers' strategies as Commentator of students' collaboration during the debriefing session.

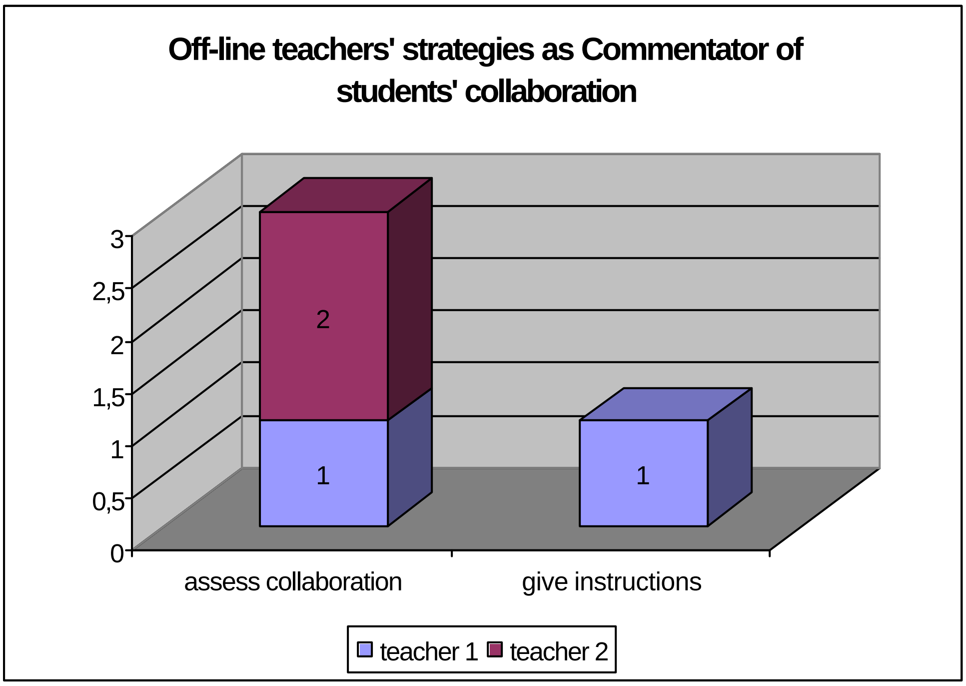


Figure 45. Teachers' strategies as Commentator of students' collaboration

Teachers' strategies as Commentator of students' knowledge during the debriefing session		
Stratégies	**Description**	**Examples**
Assess students' knowledge	Teacher assess students' knowledge concerning the subject matter to be taught	"You did some mistakes."
Comments on the way they solved the problem	Teacher comments the way students solve the problem.	"In order to answer the questions we must use our model"

Table 23. Teachers' strategies as Commentator of students' knowledge during the debriefing session

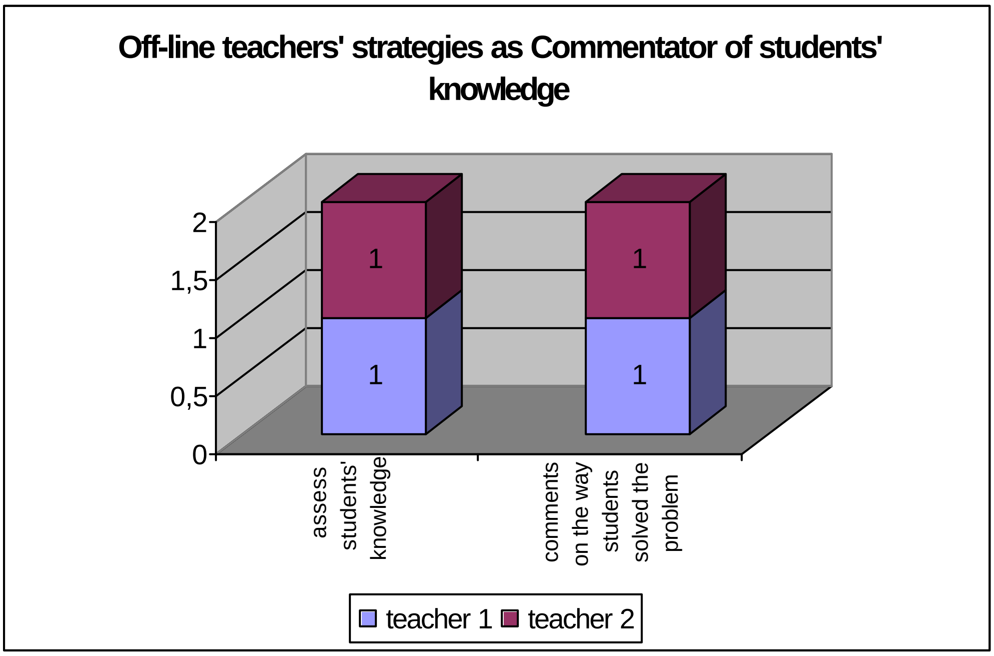


Figure 46. Teachers' strategies as Commentator of students' knowledge

In traditional classes with face-to-face collaboration, teachers usually intervene when they want to correct mistakes at the final product, to solve problems that were not solved due to lack of time and to ask students questions in order to test their knowledge. Apart from above cases, now they have the chance to intervene in order to assess collaboration and to give instructions, or when there are misconceptions (after studying history of dialogues between students of each team). The last case is very significant because misconceptions are more likely to be "resolved" if the teacher not only discusses the misconception during problem-solving but also using probing feedback and post-summarisation strategies to address them after the problem-solving phase has ended (Pilkington, 2001). So teachers after studying the collaboration analysis file didn't solely focus on students' errors or on their final product as they were used to, something that is consistent with the findings reported at (Lund & Baker, 1999).

G.I?.4.5. Conclusion

The main purpose of the present study was to examine if synchronous computer mediated collaborative problem solving is valuable in every day practice with collocated students and teachers.

Before this research implementation, our assumption was that eventually, this approach could be interesting for teachers, (especially after some practice), even though they hadn't any special instruction, neither on collaboration value, nor on teachers' effective roles under these conditions.

The analysis showed that computer supported collaborative learning provides the teacher with some new opportunities, in spite of certain difficulties (such as time consumption). This is so because learners interact through messages, and this information is available to the teacher as a resource that can be used to assess the learning that has taken place. Additionally, a teacher can monitor the actions at the shared workspace and the dialogues, during problem-solving. Viewing the details of a problem-solving interaction between students could elucidate students' puzzling behavior (Lund & Baker, 1999). Besides, making the learning process of a group explicit, the teacher can be aware of the students weak and strong points and thus be able to intervene and monitor the group more effectively using different strategies according to the situation (Daradoumis, Marques, 2000). Diagnosis is a really hard activity for teachers, and if they have the opportunity to apply it, at least to a certain degree, we consider it is significant both for teaching and learning.

The conclusion that we derived is that application was possible and that it had positive effects on teachers' strategies. Maybe teachers face the whole approach positively, in contrast with findings of other researches (Lipponen, 1999), because synchronous computer supported collaborative learning was an integrated part of the learning environment. So, we consider that the use of a networked environment for collaborative problem solving with co-present students, was legitimated. Eventually, this approach could be considered as a first step for teachers to explore more powerful approaches that the computer supported collaborative learning inspire.

Moreover, such approaches which are not far away from current teachers practices are often considered as a first step for teachers' involvement to new educational practices with technologies (Casey, 1996; Sandholtz, et al. 1997; Baki, 2000).

6.7.2.4 G.II.5 Students' points of view

According to teachers' questionnaires at the end of the session we have the following:

a. Question: Did teacher's presence help you?

Only the students that worked under teacher's attendance answered this question.

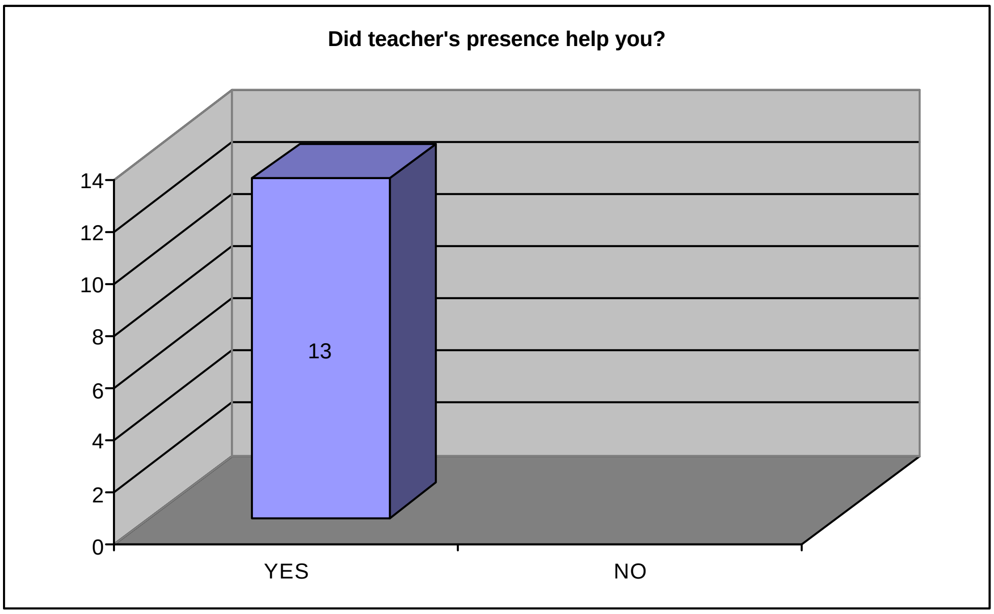


Figure 47. Students' answers to the question: *"Did teacher's presence help you*?"

As we can see all students answer positively. More concretely students' justifications were:

(a) One student answered *"He helped us not to make mistakes"*

(b) Three students answered *"He answered our questions"*

(c)One student answered *"He gave us advices and indications"*

(d) Two students answered *"He gave us immediate help when we couldn't proceed"*

(e) Four students answered *"He helped us with MS"*

(f) One student answered *"We faced difficulties that couldn't get over by ourselves"*

(g) One student answered *"Just his presence give you more freedom"*

Most of the students (around 70%) believe that the teacher provides help on cognitive matters.

b. *Question:* According to your opinion when teachers should intervene during problem-solving?

As we can conclude from the following figure, most of the students want teachers' interventions to be made when they ask for help, and not according to teachers' judgment.

From Figure 40 we can see that this is not had happened. Most of teachers' interventions were teacher-requested.

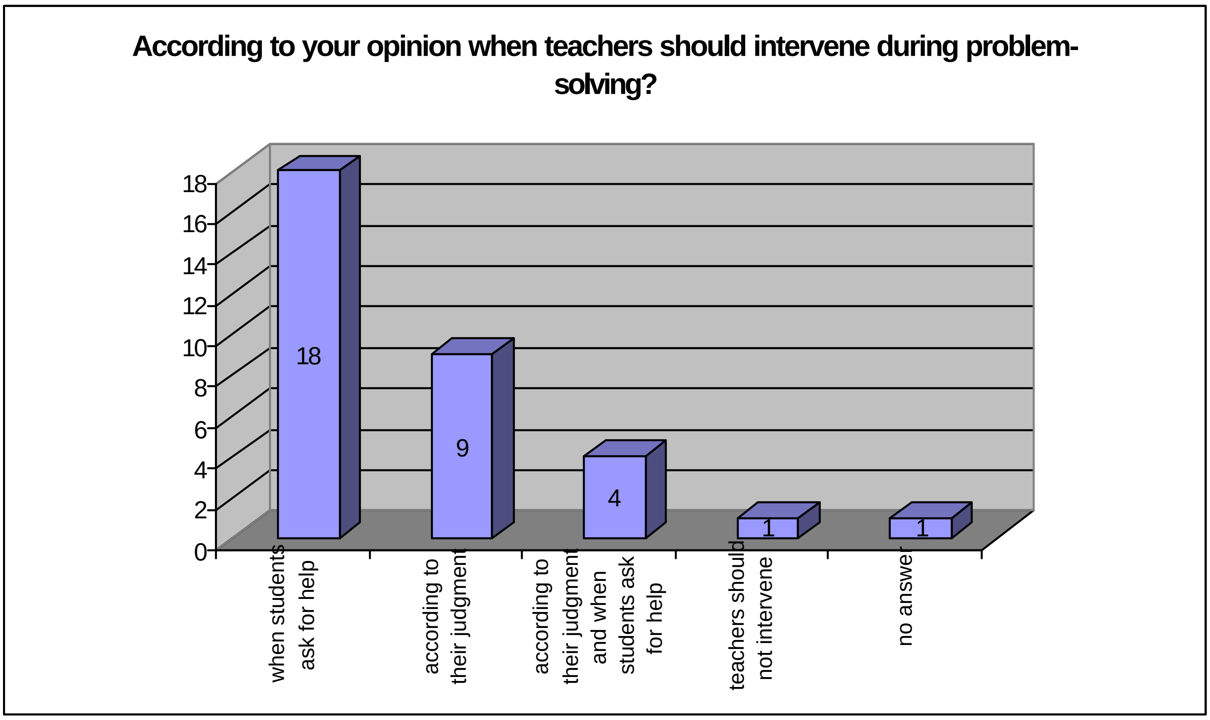


Figure 48. Students' answers to the question: "According to your opinion when teachers should intervene during problem-solving?"

Eighteen students want teachers to intervene when students ask for help, nine want teachers to intervene according to their judgment, four want both, one want the teacher not to intervene at all, while one didn't answer.

c. *Question*: Why teachers should intervene only when students ask for help?

The eighteen students, above figure, that answered that teachers should intervene during problem-solving only when students ask for it, gave the following justifications:

Students must try to solve the problems by themselves	Teachers should just answer students' questions	Teachers should help students only when they need it	Teachers should guide students and not just tell them what to do	Students don't like to be interrupted	No answer
4	1	3	2	2	6

Table 24. Students' answers to the question: "Why teachers should intervene only when students ask for help?"

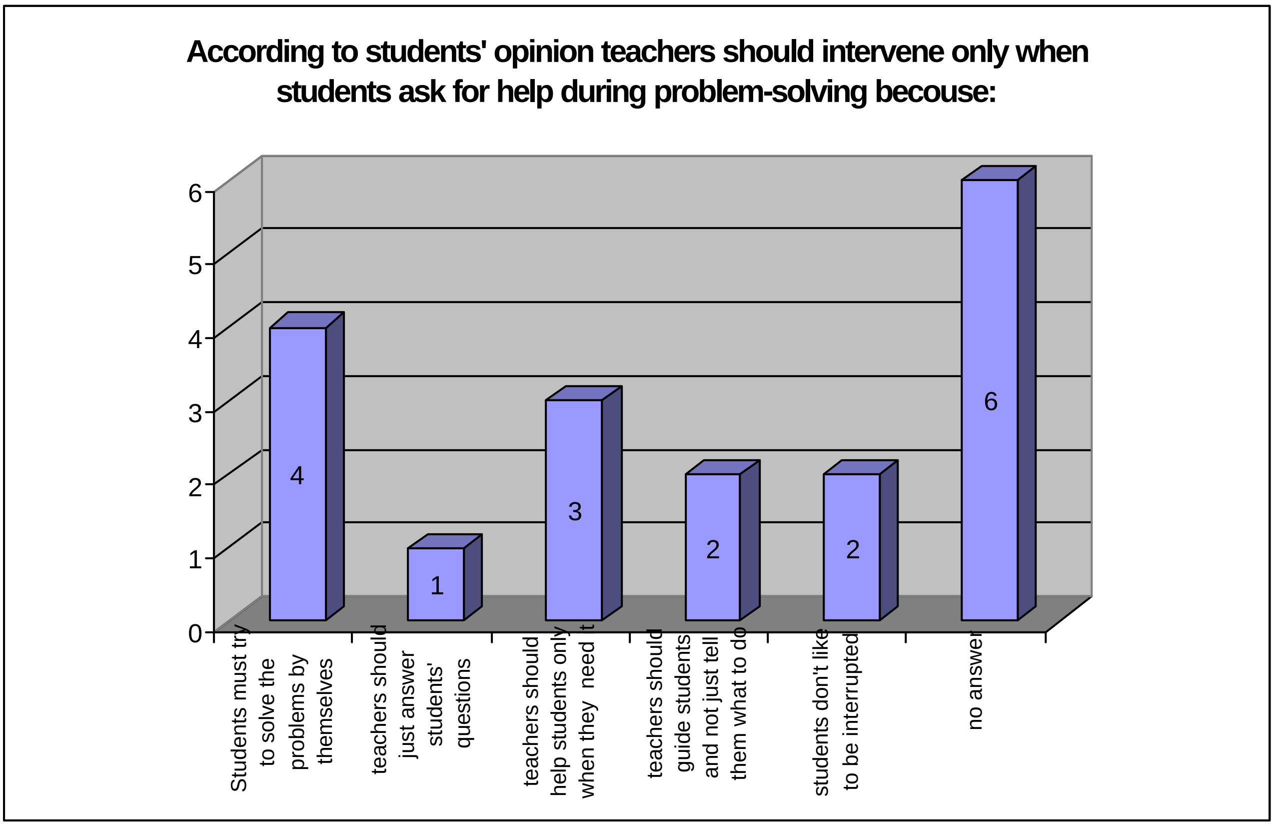


Figure 49. Students' answers to the question: "Why teachers should intervene only when students ask for help?

d. Question: Why teachers should intervene according to their judgment?

From the results of question b we can saw that nine students answered that teachers should intervene during problem-solving according to their judgment. From the next figure, which presents their justifications, about 33% answered that teachers should intervene when students can't continue. That means that these students don't want teachers to intervene too often, they want to try to solve the problem by themselves. The only difference is that they put the responsibility of intervention to teachers, not to themselves.

From the four students that answer that teachers should intervene according to their judgment and when students ask for help, Figure 48, two didn't justified the answer, one said *"because he may find mistakes but he also must answer our questions"* and the last one that *"Normally, teachers should intervene according to their judgment, but I would prefer them to intervene for answering my questions when I ask for it"*.

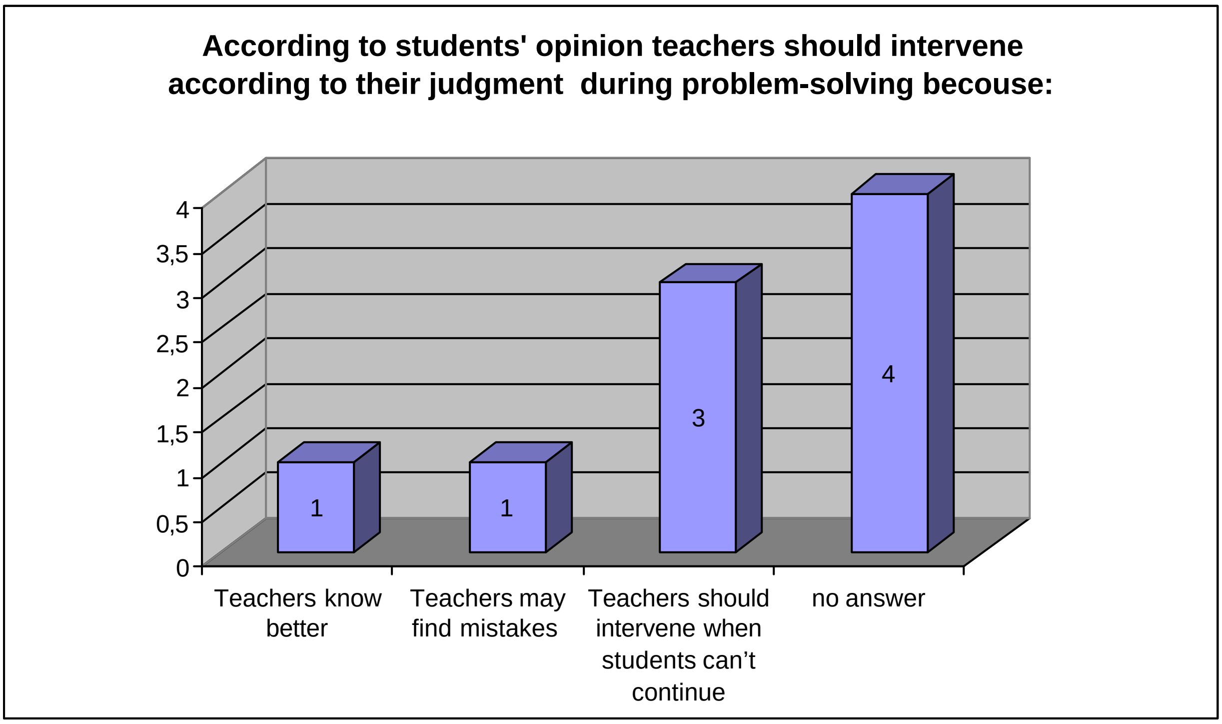


Figure 50. Students' answers to the question: "Why teachers should intervene according to their judgment"

e. Question: Why teachers should not intervene at all?

The one student who answered that the teacher shouldn't intervene during problem-solving, Figure 40, justified it by saying that *"It is annoying when the teachers intervene. Students must try to solve the problem only by themselves"*.

This student was from 2nd TEE of Rhodes, he was working with the researcher and teacher's classroom is Teacher 2. Teacher 2, as we have already mentioned, is a teacher who dominated during all phases of the activity. We can conclude that probably this is his style in general, something that may can justify student's opinion.

f. Conclusion

The above analysis showed that most of the students want teachers to intervene when students ask for it, unlike what happened during our sessions, where as we saw, most of the interventions were teacher-requested.

6.7.2.5 G.II.6 What settings are appropriate?

Students were highly motivated in all the modes of use and the quality of the collaboration can be characterized satisfactory. In the OMR mode of use the presence of the researcher affected the students and they did not preferred to collaborate online. The comparison of modes of use does not lead easily in true/false result since all the modes of use have their potentials. The most useful result of the study concerning the modes of use is that ModellingSpace can be used as a mirror for the agents in order to become conscious of their learning/teaching styles.

a. MS is neutral to learning process administration styles (democratic-centralized) and learning process participation styles (collaborative-competitive) permitting all the possible combinations to appear and it can be used as a mirror for the agents to be conscious of them.

As the previous analysis of the typical learning activity implementation shows agents have many opportunities to get involved in high quality collaborative problem solving activities in which they employ high order thinking using cognitive tools of MS. MS seems to be neutral to the students participation style (competitive, collaborative) as well as the teachers class administration (democratic or centralized). Furthermore MS can be used as a mirror in order for students and teachers to be conscious of these aspects of learning-teaching activity. For example we saw previously a democratic teacher in 5G with a coaching role during collaboration for a group of two students with the one very competitive (madragnamon). In the next collaborative activity diagrams we see a case of a centralized teacher which commands students and finally they are just watching him.

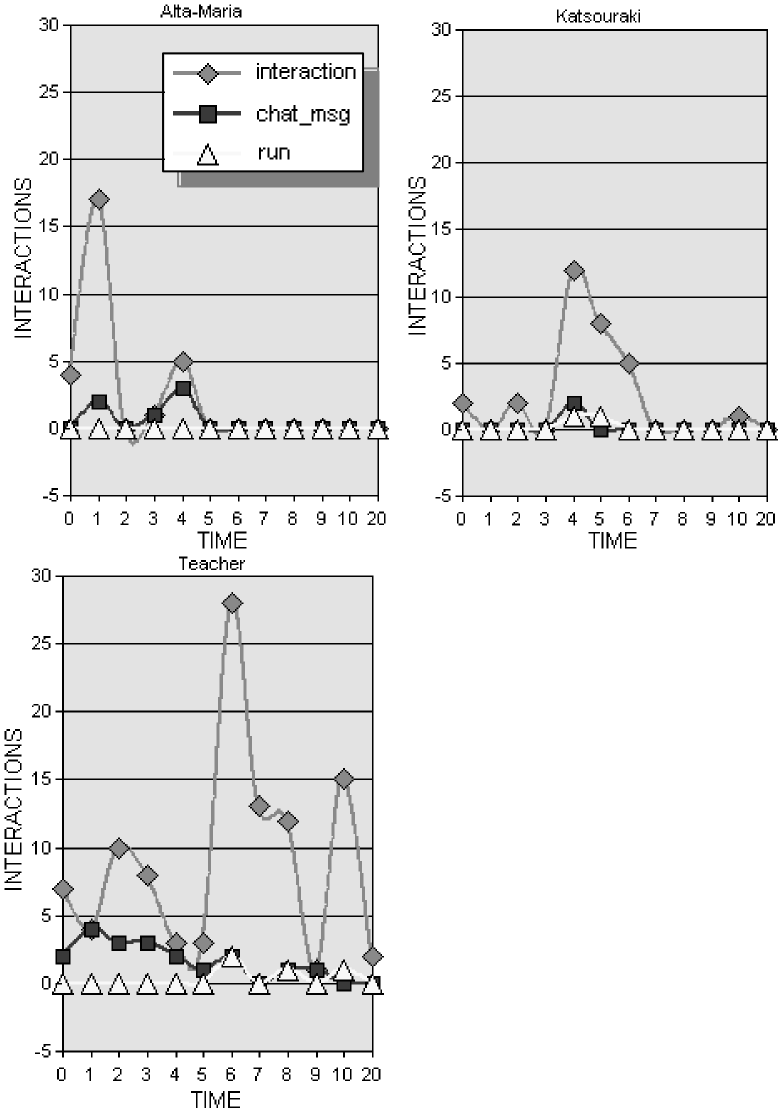


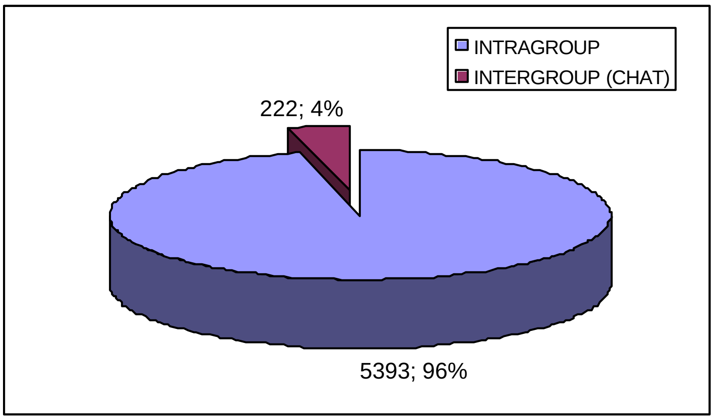
Figure 51. Interaction diagrams for a group of two students (Alta-Maria, Katsouraki) and a teacher. 12/12/2003 in TAP, Activity 2.

b. The percentage of oral messages exchanged by students sitting in front of a pc is very higher than the percentage of chat messages posted to the students supposed to be in the same group in another pc.

As can be seen in the following table students sitting in front of a pc find it much easier to exchanging oral messages between them than to write chat messages to other students sitting in another pc. Especially when there is an adult near by students tend to constitute a separate group per pc and finally cooperate than collaborate. This was the case 3 in the previous analysis.

ACTIVITIES				
9 DEC 03. 3G. Act.1.	**15 JAN 04. 5G. Act.1.**	**12 DEC 03. TAP. Act. 2.**	**17 JAN 04. 5G. Act.2**	**11 DEC 03. 3G. Act. 3.**

		G.D.	G.K.	G.D.	G.K.	G.D.	G.K.	G.D.	G.K.	G.D.	G.K.	TOTAL
MESSAGES	**INTRAGROUP**	303	375	713	764	414	417	622	717	440	628	5393
	INTERGROUP (CHAT)	13	13	31	31	21	21	25	25	21	21	222



In order to clarify more this situation we propose the following "electrical" model where the intragroup communication impedance is much lower than intergroup impendance.

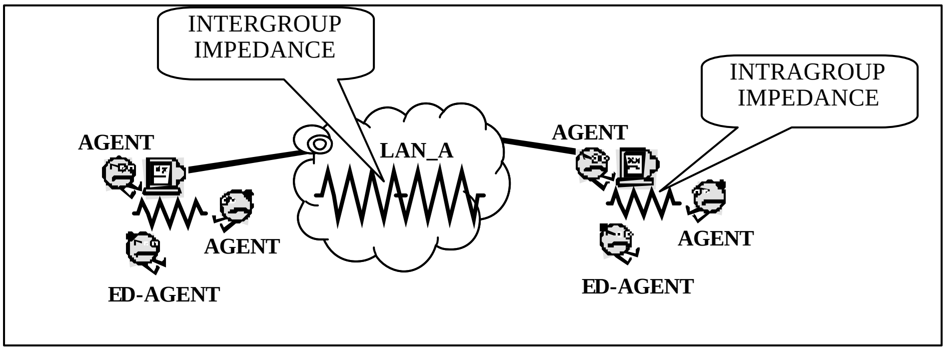


Figure 52. Electrical model of communication for the depicted mode of use. Intragroup communication is much more easy than intergroup.

So for collaboration activities is better to have one student per pc than many students in front of the pc. May be the presence of the researcher have affect significantly in the formulation of the above situation.

6.7.3 G.III. MS, Models, Modeling and students

Students approach the concept of model and the modeling process through the use of MS. It is interesting to study the effects of this situation in the cognitive schemata of students. In order to study the affection of MS familiarization and use to students ideas about models we surveyed a set of questions which more interesting results are presented in this section. The survey was implemented before and after the activities implementation.

Q1.A. HAVE YOU SEEN MODELS IN SCHOOL BOOKS

Most students are not familiar with the model concept and the modeling process. Students can have a useful introduction to the models using modeling space.

Q1.A. HAVE YOU SEEN MODELS IN SCHOOL BOOKS								
PRO			META					
YES	NULL	NO	YES	MA	DB	SE-CS	NULL	NO
0	14	16	7	2	5	1	9	14

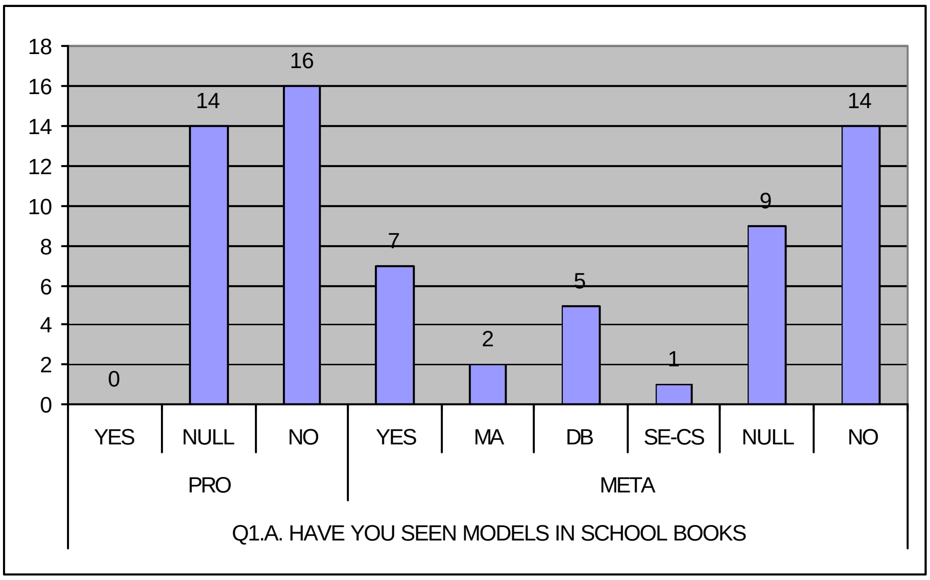


Figure 53. Student sources about models.

MA: Mathematics

DB: Databases

SE-CS: Software Engineering of computer science.

Q1.B. MENTION IMPRESSIVE MODELS

In this question students asked to mention impressive models. Many students are impressed by the models used in MS.

Q1.B. MENTION IMPRESSIVE MODELS					
PRO		META			
NULL	MS MODEL	NULL	ER	CS	MS
15	2	13	1	1	6

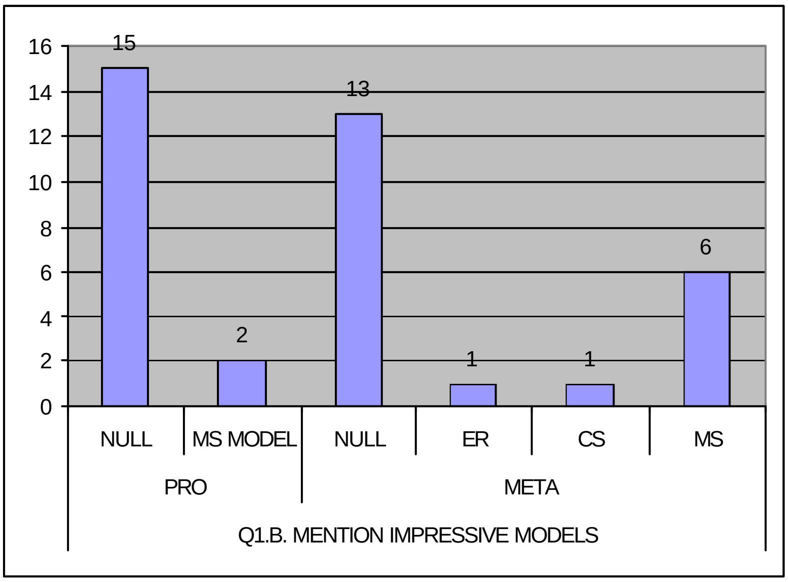


Figure 54. Students' impressive models.

MS MODEL: A model that student knew from the use of MS.

ER: Entity Relationships data model (Databases design)

CS: Computer Science.

MS: Modeling space models of the activities.

Q1.C. WHAT ARE THE GOAL OF MODELS DEVELOPMENT

This question asks students opinion about the uses of models. It is obvious that many students are formulating realistic ideas about models uses.

Q1.C. WHAT ARE THE GOAL OF MODELS DEVELOPMENT								
PRO			META					
NULL	PROBLEM SOLVING	LEARN ING	NULL	COLAB	UNDERSTAND MATHS	LEAR NING	PROBLEM SOLVING	COMPUTE
15	1	1	12	1	3	3	5	1

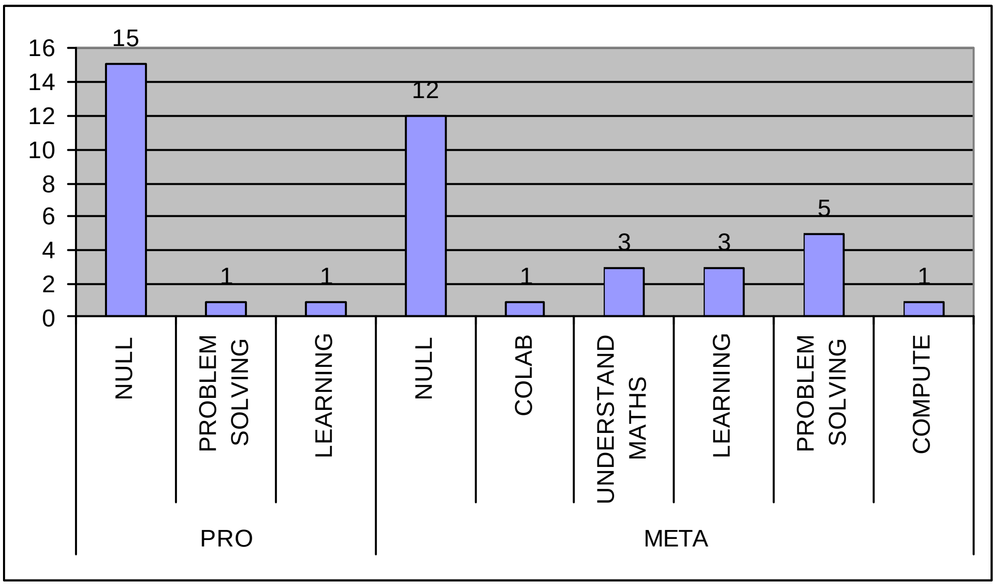


Figure 55. Models use.

Q1.D. MODELS ARE MADE OF…

After ModellingSpace use many students seem to understand that models can be developed using Paper and Pencil or Software.

Q1.D. MODELS ARE MADE OF…					
PRO			META		
NULL	PC	CAMERA	NULL	PP	PC
15	2	2	11	2	9

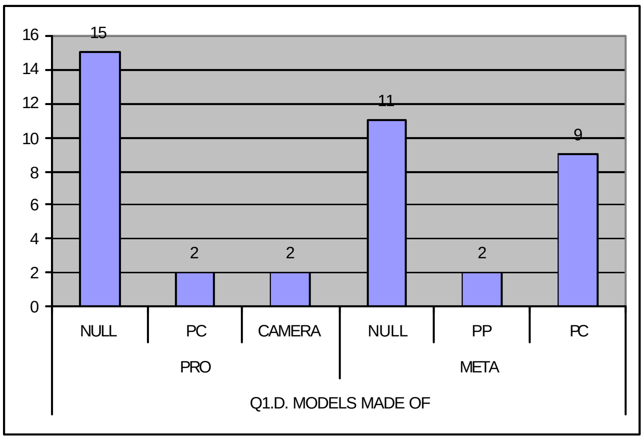


Figure 56. Model ingredients.

PP: Paper and pencil.

The above questions were in the before and after survey. The following questions concerning the use of MS for modelling were only in the after survey.

Q3.A. WHAT ARE MS MODELS CONSISTS OF

After familiarization to the MS students asked to name the building blocks of models. Most students remember the components but some of them consider graphs and value tables as model ingredients.

Q3.A. WHAT ARE MS MODELS CONSISTS OF								
META								
ENTITIES	RELATIONS	CONSTANTS	VARIABLES	FUNCTIONS	DATA-UNKNOWNS	VALUE TABLE	GRAPH	NULL
14	11	8	5	1	1	4	4	2

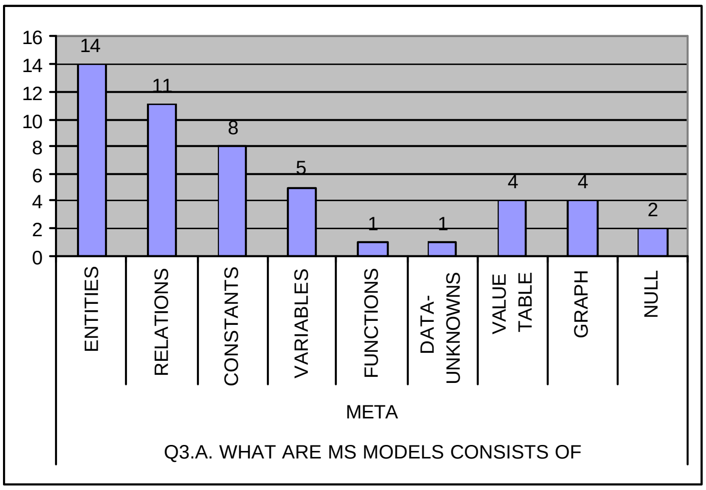


Figure 57. MS models ingredients.

Q3.B. WHAT ARE THE MAIN STAGES OF THE MODELING PROCESS

In this question students are asked to recall the main stages of the modeling process. Most of them remember more or less the basic stages.

Q3.B. WHAT ARE THE MAIN STAGES OF THE MODELING PROCESS					
META					
NULL	ENT-CON-REL-DIAG	ENT-CON-REL-RUN	ENT-CON-REL	CON-REL-RUN	REST
8	1	5	2	1	3

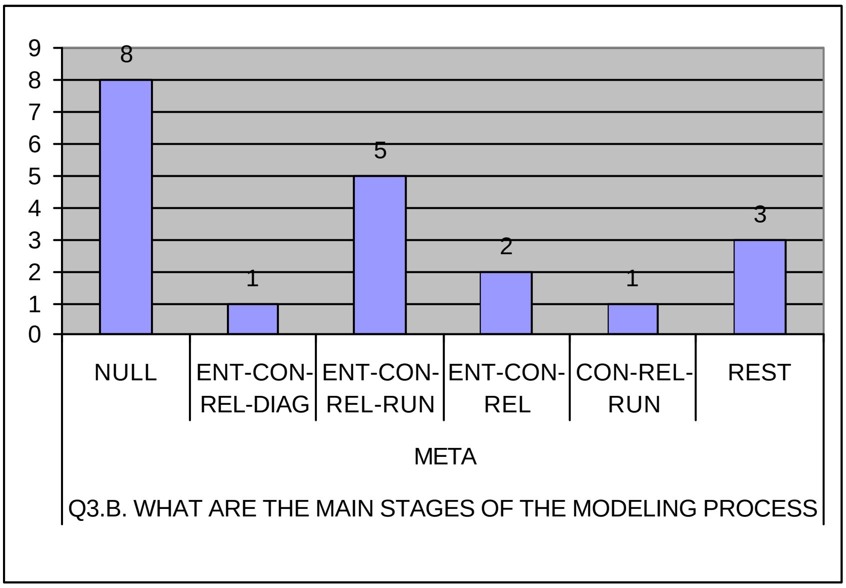


Figure 58. Modelling process stages in MS.

ENT: DEFINITION-SELECTION OF ENTITIES.

CON: ENTITIES ATTRIBUTES VALUES CONFIGURATION.

REL: DEFINITION-SELECTION OF RELATIONSHIPS

RUN: MODEL SIMULATION-EXECUTION

DIAG: PRODUCTION OF DIAGRAMS

Q3.E. WE RUN A MODEL IN ORDER…

This is a very interesting question about the students ideas concerning the execution of the model (simulation of the system). There are several layers of maturity in students ideas with more mature the ideas: *"to find errors"* and *"To see the variable values for specific time points"*. These opinions have been noted by 10 students.

Q3.E. WE RUN A MODEL IN ORDER..					
META					
NULL	PRODUCE DIAGRAM	VIEW RESULTS OF ITS ACTIVITY	FIND ERRORS	TO SEE THE VARIABLE VALUES FOR SPECIFIC TIME POINT	TO SOLVE THE PROBLEM
5	2	4	7	3	3

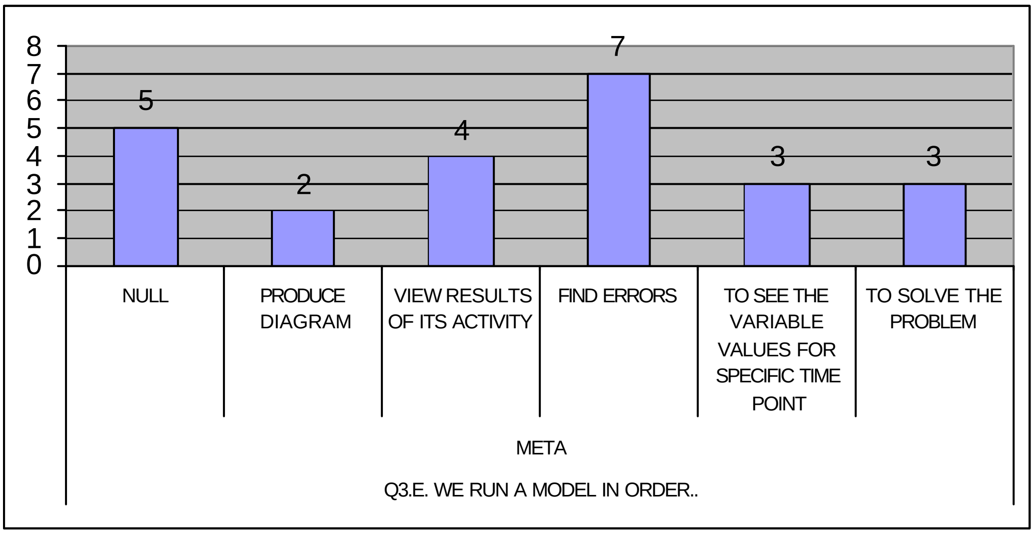


Figure 59. Ideas of students about the systems simulation.

Q3.F. A MODEL IS CORRECT IF…

In this question we ask students opinion about the correctness of a model. As in the previous question there is a variety of maturity levels in students' answers. Five students say the quite realistic opinion: *"if it computes the expected results"* but other five are satisfied if the model just runs.

Q3.F. A MODEL IS CORRECT IF..						
META						
NULL	FUNCTION AS EXPECTED	COMPUTES THE EXPECTED RESULTS	PRODUCE THE CORRECT DIAGRAM	IF IT RUNS	IF CONTAINS THE CORRECT ENTITIES-VALUES-RELATION	REST
4	1	5	2	5	3	3

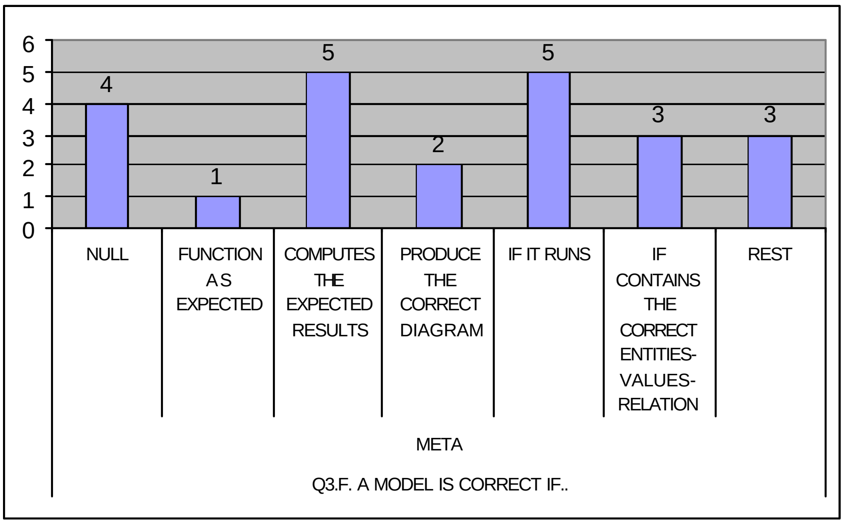


Figure 60. Ideas of students about the models validation and verification.

6.7.3.1 G.III.1. Conclusion

Modeling is a basic scientific activity and students that are conscious of model concept are approaching science from a better point of view. ModellingSpace can be used for the clarification of scientific modeling for problem solving producing multiple learning advantages for students.

6.8 CONCLUSIONS

The pedagogical evaluation and validation research implemented in Rhodes schools has analyzed ModellingSpace exploitation in real schools from several points of view. The main conclusions of the study are summarized in this section for each point of view.

a. Teachers evaluation of collaboration analysis tools

During the study teachers used the available collaboration analysis tools of ModellingSpace and in addition some more tools have been designed according to teachers' requirements.

Statistics

Most of the teachers believe that this is a useful tool, but you can't get to safe conclusions unless you have access to other analysis tools. During using *Statistics* teachers observe mostly key's possession and number of messages per participant for comparison among collaborative members and for their own assessment.

Playback

All teachers mentioned that *Playback* seems to be a useful tool, but they find that it is not so easy to use and time consuming. During using *Playback* teachers observe mostly students' mistakes during problem-solving in order to do demonstration to students.

CAF

Teachers' global point of view about CAF points out mainly its usefulness considering it as a tool presenting an overview, its justification showing that one can derive qualitative information, teaching strategies based on CAF information, the interest in the mode of use "on the fly" so as to supervise many groups at the same time. During using *CAF* teachers observe mostly the contribution of each participant taken into account the qualitative information that CAF provides. So by using CAF teachers are able to diagnose collaboration quality or cognitive problems, plan their own interventions and assess students' contributions or theirs interventions.

COPRET

Teachers' global point of view about COPRET points out mainly its usefulness considering it as atool presenting details from dialogues and actions during collaborative problem-solving, and its justification since teachers can localize students' weak points and detect misconceptions, studying students' behavior and contribution, criticize theirs interventions and analyzing interventions' results. During using *COPRET* teachers mostly observe details drom dialogues between participants and actions at the shared workspace. So teachers can have more than a general estimation about collaboration quality and an information about the existence or not of cognitive problems. This is very important since making the learning process of a group explicit, the teacher can be aware of students' weak and strong points and thus be able to intervene accordingly. Additionally teachers can assess their own interventions and regulate their behavior after studying the results of each intervention they did.

b. The meaning, the quality and the strategies of synchronous collaborative problem solving through MS, among collocated participants

In the study some interesting settings concerning collocated students collaboration have been systematically studied. The study has been developed on the following main axes:

1. Students motivation
2. Teachers points of view
3. The quality of interaction analysis
4. Teachers interventions and their consequences
5. Students points of view
6. Comparison of the collocated modes of use studied.

The main conclusions for each axis are presented bellow.

b.1. Conclusions about the students' motivation

According to the research data students are highly motivated to use ModellingSpace in collocated learning activities since they are engaged for long time periods in productive problem solving. Students can easily communicate using ModellingSpace means in most modes of use but they face difficulties to formulate a total group in case of OMR mode of use. Students in OMR prefer to collaborate by face to face communication rather than through ModellingSpace and so they formulate two cooperating groups.

b.2. Teachers point of view

Teachers' point of view about collaboration among collocated students is positive since: (a) students are motivated, something that is proved according to their opinion by the inexistence of off-task messages and students' positive attitude, (b) unlike to face-to-face collaboration students' dialogues and actions are available.

Additionally teachers notice that if they design the appropriate activities, this approach can be applied as an alternative way of teaching, for checking students' concepts and misunderstandings

b.3. The quality of interaction and collaboration

Conclusions about OME mode of use (students supervised by teacher).

Students are able to collaborate and initiate despite the presence of the teacher. Students ask for the teacher to help them whenever they need so. Teacher need to adapt to a new role in which he/she facilitates the collaboration and the negotiation instead of providing the knowledge as the only authority.

Conclusions about OXE mode of use (students collaborating unsupervised)

Despite the absence of adult's supervision students stay engaged in collaboration through ModellingSpace until they solve the activity sheet problems. This is a strong evidence of student's motivation. Students need guidance in order to develop auditing and planning project management abilities. Students are less competitive without adult's participation.

Conclusions about OMR mode of use (some students in front of a pc collaborating to another similar group with the presence of a researcher per group)

Despite the quite good use of ModellingSpace and the high motivation of the students the presence of the researcher and the possibility to have face to face communication results at lower quality collaboration in OMR mode. Students in front of a pc preferred face to face collaboration than to the subgroup in the other end of the line. In addition students gave to the researcher a typical teacher role as the performance evaluator and the knowledge authority and they decreased their possibilities to exploit real social negotiation.

b.4. Teachers interventions

The main purpose of the present study was to examine if synchronous computer mediated collaborative problem solving is valuable in every day practice with collocated students and teachers.

Before this research implementation, our assumption was that eventually, this approach could be interesting for teachers, (especially after some practice), even though they hadn't any special instruction, neither on collaboration value, nor on teachers' effective roles under these conditions.

The analysis showed that computer supported collaborative learning provides the teacher with some new opportunities, in spite of certain difficulties (such as time consumption). This is so because learners interact through messages, and this information is available to the teacher as a resource that can be used to assess the learning that has taken place. Additionally, a teacher can monitor the actions at the shared workspace and the dialogues, during problem-solving. Viewing the details of a problem-solving interaction between students could elucidate students' puzzling behavior (Lund & Baker, 1999). Besides, making the learning process of a group explicit, the teacher can be aware of the students weak and strong points and thus be able to intervene and monitor the group more effectively using different strategies according to the situation (Daradoumis, Marques, 2000). Diagnosis is a really hard activity for teachers, and if they have the opportunity to apply it, at least to a certain degree, we consider it is significant both for teaching and learning.

The conclusion that we derived is that application was possible and that it had positive effects on teachers' strategies. Maybe teachers face the whole approach positively, in contrast with findings of other researches (Lipponen, 1999), because synchronous computer supported collaborative learning was an integrated part of the learning environment. So, we consider that the use of a networked environment for collaborative problem solving with co-present students, was legitimated. Eventually, this approach could be considered as a first step for teachers to explore more powerful approaches that the computer supported collaborative learning inspire.

Moreover, such approaches which are not far away from current teachers practices are often considered as a first step for teachers' involvement to new educational practices with technologies (Casey, 1996; Sandholtz, et al. 1997; Baki, 2000).

b.5. Students points of view

As far as the students' opinion is concerned students believe that this approach gives possibilities for better collaboration and communication and helps them to develop the ability of expression of their thoughts. Finally students' motivation is expressed through their willing to participate again in collaborative activities using ModellingSpace.

The above analysis showed that most of the students want teachers to intervene when students ask for it, unlike what happened during our sessions, where as we saw, most of the interventions were teacher-requested.

b.6 Settings comparison

Students were highly motivated in all the modes of use and the quality of the collaboration was satisfactory. In the OMR mode of use the presence of the researcher affected the students and they did not preferred to collaborate online. The comparison of modes of use does not lead easily in true/false result since all the modes of use have their potentials. A very useful result of the study concerning the modes of use is that ModellingSpace can be used as a mirror for the agents in order to become conscious of their learning/teaching styles.

d. modeling conclusions

Modeling is a basic scientific activity and students that are conscious of model concept are approaching science from a better point of view. ModellingSpace can be used for the clarification of scientific modeling for problem solving producing multiple learning advantages for students.

7 GENERAL CONCLUSIONS

7.1 (I) Conclusions from Cognitive Evaluation of ModellingSpace technology based environment

A number of studies had as objective to investigate the cognitive activities of the students using ModellingSpace; The main support for these cognitive activities can be attributed mainly to the technology based learning environment, given that students do not work into the system of the class [other groups of students, teacher or even other educational material (e.g. worksheets)]

- Comparison of ModellingSpace with another modelling environment based only on scientific modelling primitives: Interacting with 'ModellingSpace, even the pupils of lower secondary school were able to carry out the experiment thanks to the visualization of the entities, with the expression of the properties in natural language rather than by letter symbols and with the formalization of the relations by means of graphic codes (of the directed arrows various lengths to translate the importance of the variation).(see unit 3.3.)

- The comparison between the pupils'behavior in the two types of technology based learning environments underlines the need of a comparison and linking between the aspects of reality, their conceptualisation and the symbolic notations of those. Learning, specially in some disciplines (Physics) is based in fact on this type of comparison. It is shown that the representation of entities, properties and relations in a figurative form enables students to use the technology based learning environment in a meaningful way compared to the world of actions, objects and events.

  This type of technology based learning environment thus seems to help pupils with the conceptualisation of the situations. This enables them to be detached from the actions and the perceived events for centring on the relations between analytical characteristics of the situations. The assumption advanced by the designers of this technology based learning environment is that this cognitive treatment of the situations is a possible precursor of a quantitative treatment implying of the expressed physical dimensions in a formal way. This aspect is partially validated by the observations reported in a specific context of the study (experimental activities proceed the work with the educational software). (see unit 3.3.)

- The role and the significance of the animation based object-oriented entities: The simulation through animation – representation of a real object-- seems to play a significant role: at first place, it stresses the students' alternative ideas and it furthers structures the content of vector-concepts like those of velocity and position after a short period. More specifically, these entities (a) highlight the dynamic content of kinematic concepts (in opposition to the static representation of books); and (b) students understood the vectorial aspects of concepts (the sign of velocity, disassociating /differentiating it from the change in velocity value as well as from the position of the moving object in relation to the starting point. (see unit 4.4.1). The case study report presents research results on the effectiveness of a specific category of entities (the object-oriented entities with specific representation of motion variables), to make appear students misconceptions related to specific concepts (position, velocity as vectorial concepts) as well as their appropriateness to make students ideas evolve to the scientific ones.

- The observations related to pupils (12 years old) at the end of the cycle of primary education put forward the fact that the pupils of this level are able to use the ModellingSpace software. The selected entities are correctly interpreted by the pupils. However, the interpretation of simulations reveal obstacles already described in other studies as, for example, the interpretation of the modifications in terms of sequential or topological relations. At this school level it seems that a preliminary work about the signification of relation and simulation is benefit. (see unit 3.2.)

- The results obtained support the hypothesis that ModellingSpace constitutes an appropriate tool to help pupils to understand the transformations of the situations into relational terms. Modelling through ModellingSpace could support students to identify the factors play a role in the phenomenon under study and they can express co-variations among variables, in a most important degree than working with real experiments with objects. (see unit 3.2.)

- Finally, Research results (see case 2) draw attention to the cognitive benefit of the use of the technology based learning environment, if it is preceded by an experimental activity with the relevant objects, and thus specially for young students (see unit 3.2.)

- Comparison of two settings: collaboration side by side (in front of PC) with collaboration through ModellingSpace in a shared workspace, during activities of concept map creation.

  The written exchanges through chat are extremely rich as well by the contents of the exchanges as by the structure of the exchanges. Paradoxically, the exchanges are more successful in the written exchanges than in the oral exchanges where the topic of the exchange often escapes the partner. Written statements (chat) do not respect French standard. The writing is often phonetic and uses the short cuts used in the texto sent by cellular telephone.

It seems that the strategies employed by students vary according the interactional context. When the partners are together on the same workstation, they make much more actions and speak much. When they are separated, they plan better their activities. But finally, the conceptual maps constructed are nearly equivalent. So, we can consider that the distant context is more favourable to the learning of planning activities and cooperative attitude.

7.2 (II) Conclusions from Evaluation of ModellingSpace environment (technology based learning environment, learning activities, students' worksheets), in school contexts

A number of cases studies report are presented that have taken place under conditions having an ecological validity. In these cases, the evaluation of the innovation is conditioned by a multitude of factors human as well technological ones. It is to be noticed that the students' progress over the modeling activities' sessions through the technology based learning environment has to be attributed to the combination of a number of factors: the ModellingSpace environment, the specific learning activities (and their design), the corresponding worksheets, the discussions among groups and the discussions among students' groups and teacher, the teachers' strategies and not only to the technology based learning environment itself.

Case studies in schools, involve: semiquantitative relations, qualitative concept maps, quantitative relations, different kind of entities. These case studies have taken place mainly in the frame of : mathematics courses, science physics courses. Students participating were mostly (a) at the age of (11-12 years old), and (b) at the age of 14-15 years old.

⇨ ***Can Young students (e.g. 12 years old) express themselves with "semiquantitative relations"? Interaction with MS, could support them in the learning process ?:***

Young students can express themselves through semiquantitative relations. But, it is to be taken into account that this issue, it is not the unique & central issue in order to work on modelling activities with MS. Additionaly, the topics that students were involved to discuss and they were able to contribute to these discussions were the following:

- The factors that influence the phenomenon and the distinction among them
- Students can express themselves, in terms of intuitive concepts: The most significant is that students progress over the sessions on: concepts construction (concepts that are implicated by each phenomenon under study), verbalization and distinction among them. This is a significant step over scientific concepts' construction & learning. In almost all the groups, we can infer an evolution, on:

(h) problem analysis (clarifying the central question of the problem),

(i) intervening factors' identification,

(j) concepts use, concepts verbalisation ,

From all the studies is revealed, that in all the cases, the most important significant and clear cognitive gain is in terms of conceptualization and scientific concepts construction and learning.

⇨ ***What are young students' difficulties during interaction with MS involving semiquantitative relations ?***

All the students of 12 years old had difficulties on the following:

(1.) To conclude about relations, when the simulation of entities is not produced or when simulation's behavior is not interpreted well. The eventual incapacity to interpret the simulation's behavior leads to ad hoc uses of various variables (and/or entities), relations, and values of variables.

In some cases, children had to observe and regulate the algebraic values of each variable, in order to examine the compatibility among the values of variables, so as the expected simulation to be produced. It is not easy for so young students, to reason in a semiquantitative way (in terms of relations), and in the same time to have to think in a strong quantitative way, in order to make appear the simulation.

(2.) The difficulty to understand the meaning of the constant of a proportional relation among two variables, and its correspondence with the physical status of this constant: a third concept that must be linked with a specific manner (e.g. the flow of tap is the constant into the relation of the proportionality between time and volume of the water into the recipient. Students must link this variable to the relation of proportionality. This indication does not correspond to a natural way of thinking for children).

(3.) The distinction between Independent and dependent variable. The discussion on this distinction has to be continued with a number of examples during a range of different learning activities.

For some groups was easier to cope with these difficulties, while for some others was harder.Students of 14-15 years old have similar difficulties, but they can cope with them easier.

The difficulties are less for students 12 years old, during semiquantitative models creation, when :

(g) the distinction between independent and dependent variables was obvious in this case, given that it was directly related to students' causal actions during real object experiments,

(h) the relation of proportionality implicate only two variables and not three ones (there is not a third variable corresponding to the 'constant' of the relation),

(i) the available object oriented entities that may be linked into models, have compatible values (prescribed by the designers of these entities). In this case students has not to be involved in this reasoning aspect of clear quantitative nature.

In all the cases, it has to be noted that even if some students had important difficulties, in the beginning, they have not lost their interest and their motivation to continue work with MS. Almost all of them seem very motivated to continue the activities with MS. The most significant is that students recognise that they have learned something specific, and they have the awareness of some of them (they are able to mention them).

⇨ ***ModellingSpace support students when they work with qualitative relations, creating Concept maps?***

Students 12 years old, progress in concept maps creations, (the depth of the concepts connections shows an important increase in the final maps, thus students seems to achieve better organization and hierarchy of the meanings). As far as the map structure of the concept maps is concerned, this structure were improved and evolved in more complex and complete forms.

When students work with concept maps, have not difficulties due to the ModellingSpace environment itself.

⇨ ***ModellingSpace support students when they work with quantitative relations, forming algebraic equations?***

Students 14-15 years old, reveal interesting conceptual difficulties when they start to express algebraic equations. The learning progress during quantitative models creation seems to be learning significant.

7.3 (III) Modelling Activities in settings of synchronous Collaboration through ModellingSpace, involving students collocated into the same class

(A) The meaning, the quality and the strategies of synchronous collaborative problem solving through MS, among collocated participants

Students' motivation in collaborative settings

According to the research data students are highly motivated to use ModellingSpace in collocated learning activities since they are engaged for long time periods in productive problem solving. Students can easily communicate using ModellingSpace means in most modes of use but they face difficulties to formulate a total group in case of OMR (two students in front of a pc collaborating to another similar group with the presence of a researcher per group mode of use).

Teachers' point of view

Teachers' point of view about collaboration among collocated students is positive since: (a) students are motivated, something that is proved according to their opinion by the inexistence of off-task messages and students' positive attitude, (b) unlike to face-to-face collaboration students' dialogues and actions are available.

Additionally, teachers notice that if they design the appropriate activities, this approach can be applied as an alternative way of teaching, for diagnose students' concepts and misunderstandings.

The analysis showed that computer supported collaborative learning provides the teacher with some new opportunities, in spite of certain difficulties (such as time consumption). This is so because learners interact through messages, and this information is available to the teacher as a resource that can be used to assess the learning that has taken place. Additionally, a teacher can monitor the actions at the shared workspace and the dialogues, during problem-solving, and thus can elucidate students' puzzling behaviour. Besides, making the learning process of a group explicit, the teacher can be aware of the students weak and strong points, misconceptions and difficulties and thus be able to intervene and monitor the group more effectively using different strategies according to the situation. Diagnosis is a really hard activity for teachers, and if they have the opportunity to apply it, at least to a certain degree, we consider it is significant both for teaching and learning.

The quality of interaction and collaboration in three different collaborative settings

Conclusions about OME mode of use (two students supervised by teacher): Students are able to collaborate and initiate despite the presence of the teacher. Students ask for the teacher to help them whenever they need so. Teacher need to adapt himself to a new role in which he/she facilitates the collaboration and the negotiation instead of providing the knowledge as the only authority.

Conclusions about OXE mode of use (two students collaborating unsupervised via MS): Despite the absence of adult's supervision students stay engaged in collaboration through ModellingSpace until they solve the activity sheet problems. This is a strong evidence of student's motivation. Students need guidance in order to develop auditing and planning project management abilities. Students are less competitive without adult's participation.

Conclusions about OMR mode of use (two students in front of a pc collaborating to another similar group with the presence of a researcher per group): Despite the quite good use of ModellingSpace and the high motivation of the students the presence of the researcher and the possibility to have face to face communication results at lower quality collaboration in OMR mode. Students in front of a pc preferred face to face collaboration than to the subgroup in the other end of the line. In addition students gave to the researcher a typical teacher role as the performance evaluator and the knowledge authority and they decreased their possibilities to exploit real social negotiation.

Settings comparison: Students were highly motivated in all the modes of use and the quality of the collaboration was satisfactory. In the OMR mode of use the presence of the researcher affected the students and they did not preferred to collaborate online. The comparison of modes of use does not lead easily in true/false result since all the modes of use have their potentials. A very useful result of the study concerning the modes of use is that ModellingSpace can be used as a mirror for the agents in order to become conscious of their learning/teaching styles.

Teachers interventions

The conclusion that we derived is that application was possible and that it had positive effects on teachers' strategies. Maybe teachers face the whole approach positively, in contrast with findings of other researches (Lipponen, 1999), because synchronous computer supported collaborative learning was an integrated part of the learning environment. So, we consider that the use of a networked environment for collaborative problem solving with co-present students, was legitimated. Eventually, this approach could be considered as a first step for teachers to explore more powerful approaches that the computer supported collaborative learning inspire.

Moreover, such approaches, which are not far away from current teachers practices are often considered as a first step for teachers' involvement to new educational practices with technologies

Students points of view

As far as the students' opinion is concerned students believe that this approach gives possibilities for better collaboration and communication and helps them to develop the ability of expression of their thoughts. Students' motivation is expressed through their willing to participate again in collaborative activities using ModellingSpace.

The above analysis showed that most of the students want teachers to intervene when students ask for it, unlike what happened during our sessions, where as we saw, most of the interventions were teacher-requested.

(B) Synchronous Collaborative Modelling Process through ModellingSpace, and Learning on Modelling.

Students' Answers to specific questionnaires (pre & post activity questionnaires) show us, that students have profit from synchronous collaborative activity, in the learning process related to modeling process, models' status, and kind of models. Modeling is a basic scientific activity and students that are conscious of model concept are approaching science from a better point of view. ModellingSpace can be used for the clarification of scientific modeling for problem solving producing multiple learning advantages for students.

Most of students becomes able to formulate realistic and appropriate ideas about (a) models uses, (b) models ‘components’, (c) modeling phases, (d) when a model can be considered as ‘correct’.

(IV) Teachers evaluation of Interaction and Collaboration Analysis Tools

During the study teachers used the available collaboration analysis tools of ModellingSpace and in addition some more tools have been designed according to teachers’ requirements.

Statistics: Most of the teachers believe that this is a useful tool, During using *Statistics* teachers observe mostly key’s possession and number of messages per participant for comparison among collaborative members and for their own assessment (when a teacher intervenes during collaboration between two students).

Playback: All teachers mentioned that *Playback* seems to be a useful tool, but they find that it is not so easy to use and most important it is time consuming. Teachers sometimes use Playback in order to do demonstration to students.

CAF: Teachers’ global point of view about CAF points out mainly its usefulness considering it as a tool presenting an overview, from which they can derive qualitative information. So by using CAF teachers are able to diagnose collaboration quality or cognitive problems, plan their own interventions and assess students’ contributions or theirs interventions.

COPRET: Teachers’ global point of view about COPRET points out mainly its usefulness considering it as a tool presenting details from dialogues and actions during collaborative problem-solving, and its justification since teachers can localize students’ weak points and detect misconceptions, studying students’ behavior and contribution, criticizing their owns interventions and analyzing interventions’ results. During using *COPRET* teachers are able to observe details from dialogues between participants and actions at the shared workspace. So teachers become able to identify specific cognitive difficulties as well as eventual isconceptions. Additionally teachers can assess their own interventions and regulate their behavior after studying the results of each intervention they did.