PART 4: ICT AND OTHER RESOURCES FOR TEACHING/LEARNING SCIENCE

Co-editors: *Patricia Marzin and Jari Lavonen*

Design and use of resources and environments for teaching/learning science: ICT and TEL in science education, other resources (science textbooks, teaching sequences, etc.).

This part corresponds to strand 4. It contains 18 papers.

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ICT AND OTHER RESOURCES FOR TEACHING/LEARNING SCIENCE

THE CONSTRUCTION OF MEANING IN SCIENCE CLASS WITH USING A DIGITAL LEARNING OBJECT.

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Abstract: In this article, the purpose will be argue and discuss dialogics interactions that happen in a science class of basic teaching, and if they had produce means with the prop of a Information Technology and (IT). These interactions will be analyzed under the point of view of an analytic tool (MORTIMER and SCOTT, 2002) with the Bakhtin dialogics forecasting.

Keywords: science class, semiotic mediation, speech genres.

INTRODUCTION

In the lastest years, the Science Teaching has enfatized the Human being as active participant in the context in that lives. The influence is the both directions. Looking at this situation, the focus is on the language. According to Vygotsky (2000) the language is an instrumental activity. So, researches in Sciences Educating with its center in the nature of interactions between teachers and students to build scientific knowledge has grown since the late decade (MACHADO, 1999; MORTIMER, 2000; SUTTON 1997; MARTINS et al, 1999). In this article, the purpose will be argue and discuss dialogics interactions that happen in an science class of basic teaching, and if they had produce means with the prop of a Information Technology(IT). These interactions will be analyzed under the point of view of an analytic tool (MORTIMER, 2002) with the Bakhtin dialogics forecasting.

LEARNING OBJECT AS A METACOGNITIVITY TOOL

This work has an objective to argue and discuss briefly that through interactions between teacher and student. It was possible to aid in the building of meanings about the digestive system in a classroom with the use of an object to approach built with the focus to teaching for improve metacognitive tools of students, taking like reference Bakhtin theories. ITs are instruments created by men to act on the nature or the material reality (VYGOTSKY, 1991). Since the last decade studies come indicating that the use of a learning object (LO) can to presentate a sociodiscursive built, when this presents a dialogic relations between student and teacher (KOZULIN, 2003; AFFONSO, 2008). In this work interest us is how the Theory of L.S Vygotsky realize this language.

Semiotic Mediation in Vygotsky and the sign for Bakhtin.

To Vygotsky, the language is an instrumental activity and means fundamentally two things:

1 - That it is ever mediated by instruments,

2 - and these instruments are created by men in function of the nature of actions planned by him.

In this way, to Bakhtin, these instruments are signs and then, ideology's products. And, as the ideology has a meaning and it is a part of a reality (natural or social reality) as all physic body. The sign is an instrument of production or a consumption product. But otherwise of them it also reflects and refracts another reality that it is exterior. The existence of sing is nothing more than the materialization of this communication. In this fact is that consist all of nature of ideological sings. But this semiotic area and this continuous paper of social communication as a conditioning factor didn't appears in anyone place more clear and complete than in the language. The word is an ideological phenomenon in excellence (WERTSCH, 1991). It meeting point between Vygotsky and Bakhtin theories is the semiotical mediation. To Vygotsky it's grounded beyond the language, it is in interactivies' situations. These situations become viable the mechanism of internalization, that means, the inner reconstruction of an external operation (VYGOTSKY, 2000).

In this article, the purpose will be argue and discuss dialogic interactions that happen in a science class of basic teaching, and if they had produce means with the prop of an IT. The IT used in this work was the LO, Route food (Figure 1). These interactions will be analyzed under the point of view of an analytic tool (MORTIMER and SCOTT, 2002) with the Bakhtin dialogic forecasting.

Figure 1 – LO's Route food screen

METHODOLGY AND RESULTS' DISCUSS

The presenté analysis in this article it's grounded in the analytical tool of Mortimer and Scott (2002). This tool shows how the kinds of communicative approaching are produced through teachers interventions . Analyzing the actuation form as the teacher done to guide the interactions that aid in the building of meanings in science classroom. The tool is the product of a tentative to develop a writing language do describe the genre of discuss (BAKHTIN, 1986) in the science classrooms. The survey was conducted in a State school with elementary school students from 13 to 14 years. The methodology used in this research was qualitative type, which contain detail data and they are related to people, places and talk, and it demand complex statistic treatment (BOGDAN & BIKLEN, 1994).

Table 1 – Analytical Tool to analyze the interactions and the production of meanings in science class (MORTIMER and SCOTT, 2002).

Analysis aspects	Teachin' phocus	Approaching	Acts
	Teacher' s intents	communicativity approaching	Interation Patterns
	Contents		Searcher's interventions

In this article the emphasis was given in the teacher's intents and in the teacher's interventions. In these aspects were really happen these dialogical interactions between teacher and student. Nevertheless, the contents of LO was teaching focus being elaborated in the wholeness of process of human digest. The communicative approaching occurred through the use of this IT. The approaching having like mainly: the dialogical and the authority- (WERTSCH, 1991).

In these aspects were really happen these dialogical interactions between teacher and student. Nevertheless, the contents of LO was teaching focus being elaborated in the wholeness of process of human digest. The communicative approaching occurred through the use of this IT. The approaching having like mainly: the dialogical and the authority (WERTSCH, 1991).The dialogical approaching happened when students told the trajectory of the feeding contents through the gastric-intestinal handle (Figure 2).
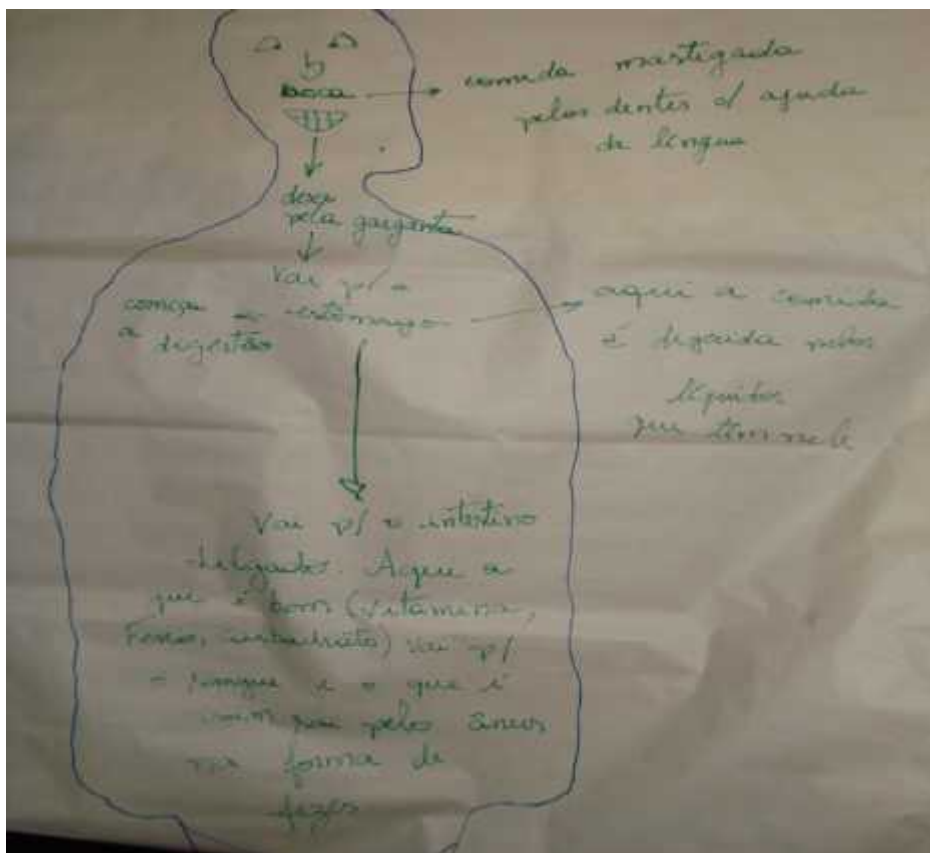

Fig. 2 – Students'_drawing about told the trajectory of the feeding.

But traces of authority approaches have been saw when the searcher putted only her point of view and only her voice was heard. In this episode a bigger interaction between searcher and students were done, with bigger relevancy to the student's initiative. However, the mainly objective of this study was the teacher's intentions. The problem was to engage students in the way intellectual and emotional to build meaning through the LO using.

However, the mainly objective of this study was the teacher's intentions. The problem was to engage students in the way intellectual and emotional to build meaning through the LO using. The students' visions about the digestive system of human being were explored by the oral and writing language, this last in the way of drawings. The LO introduced the scientific concepts. In this way, the technology was incorporated to the social plan of classroom. The simulations and interactive images from LO given support to the concepts' internalization and the building of students own meanings about the topics that were studied.

Beyond the dialogic/authority approaching, the simulations and interactive images' LO furnished metacognitive tools to aid in the building of meanings started the concepts exteriorization, as enunciated, and his posterior internalization. The internalized concepts could be watched when students named the organs of the digestive system in the final activity of the class.

During the searcher's intervention analyzed that to explore ideas about students' digestion watched that the signs that was presented by the students was only a reflex of theirs reality (BAKHTIN, 1986). In the intervention were explored students' ideas about theirs nourishment habits and about the act of to choke - a concept raised by the students. Starting this, the question selected about to choking trade the main expressed: the physician process of the closing of the glottis (Figure 3).
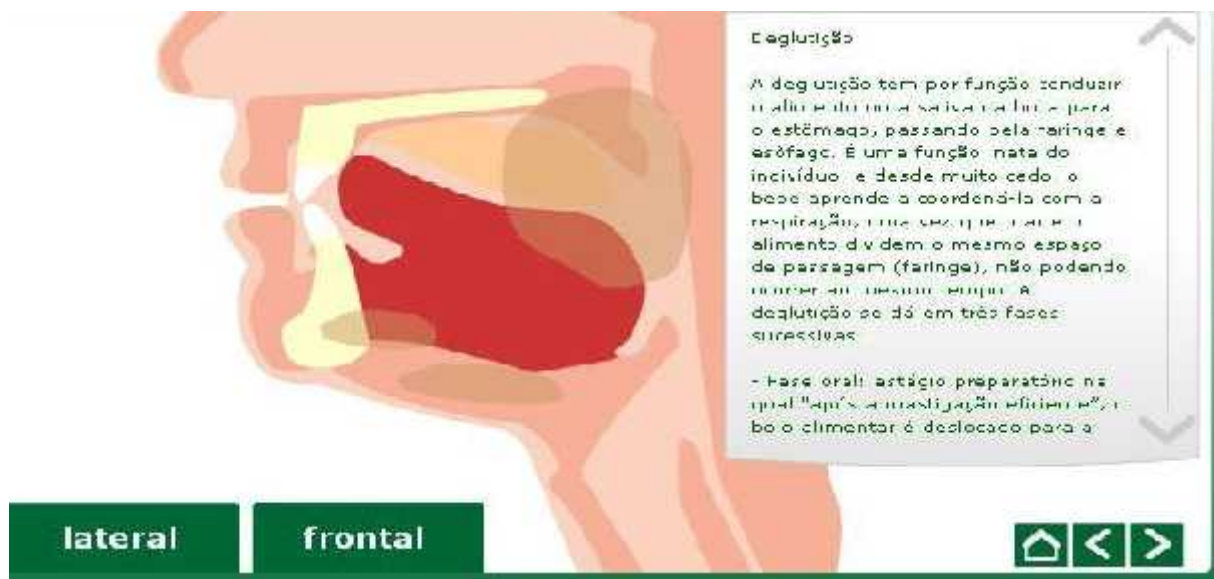
Fig. 3 – Physician process of the closing of the glottis screen visualization.

In this point was requested to the students that repeat the scientific concept. In this way, the internalizations' steps described by Vygotsky (2000) could be watched. To the repeating this concept the students start to re-organized the ideas of them. To Vygotsky (2000) an external activity is rebuilt and begins to happen internally. By the way students attributed the fact of feeling suffocated to the coming of nourishments through trachea with the sentence:

Student: *the nourishment comes through the wrong hole!*

Being follow by the exclamation:

Student: *Blame this we choke!* That means to them don't close the glottis.

CONCLUSIONS AND IMPLICATIONS

Ending, signs can be realized as internalized since that all the sign is part of the reality that enunciated it, to Bakhtin (1986). This work was influenced by researchers that have studied the interactions in the sciences class and in the way as new meanings are developed through of ways of verbal and no-verbal expressions. Patterns of discuss that take advantage of others in the sciences classrooms are so several and likewise they consist in a genre of steady discuss that will be the focus of analyses of ours (MORTIMER and SCOTT, 2002). To sum up the results through done activities was possible to watch Bakhtin premise (1981) where the *sign opposite itself to another sign the conscience herself only can rise and assure itself like reality through material incarnation of signs*, however, students took conscience about concepts over bodies organs of digestive system when they named them in a draw in this way. students. Ending, it understood that the interactions that happen were so primary genre (students' speeches, prejudicing about scientifics concepts) and secondary genre. The discursive genre was presented in the whole LO was the secondary (ideological) genre. And so, the teacher intent to teach the content was concluded and a scientific discuss was done.

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TWO GRAPHS DON'T MAKE A WHOLE: THE SYNTHESIS OF DISPARATE GRAPHS IN INQUIRY-BASED SCIENCE LEARNING

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Abstract: A comparative synthesis of multiple graphs is a common practice in scientists' work as well as in everyday contexts. This process involves elements of a meta-analytic approach, such as computation of effect size measures. We present findings from classroom enactments in Israeli and Cypriot high schools, in which cultivating students' graph meta-analysis skills was one aspect of fostering scientific literacy through an inquiry-based learning environment on socio-scientific dilemmas. The topic of the environment was "How can we choose the best smoking cessation aid?" and it required students to compare four smoking cessation treatments using graphs modified from recently published scientific articles. The specific task which is the focus of this paper required students to merge data from two line graphs, in order to rank the treatments by their efficiency, defined as abstinence from smoking. In contrast with a previous pilot study, most of the students ranked the treatments correctly, and an examination of students' justification for their rankings indicated a significant improvement in the quality of arguments. A comparison of pre- and post-enactment responses to graph synthesis tasks showed a significant improvement but on the other hand indicated that graph synthesis is a demanding task for most of the students, even following a focused intervention. Our findings highlight the challenges that learners and teachers encountered and their implications for future instruction and design.

INTRODUCTION

Scientists conducting a literature review or lay-people searching the web often encounter the same conundrum: making sense of an abundance of data sources that provide partial answers to their question. This creates a need to compare and synthesize the different pieces of information into a coherent whole. For example, different scientific articles that deal with similar research questions may test different variables, or operationalize the same variables in different ways. In such cases, a simple aggregation of the information can yield erroneous conclusions. Instead, meta-analytic steps, such as using effect size to normalize findings to a common scale, need to be taken to juxtapose and synthesize the information.

Synthetic skills may be considered a subset of procedural scientific literacy skills (Bybee, 1997), because they involve credibility judgments and allocation of different weights to multiple data pieces. Despite the fact that the use of meta-analytic methods and effect size measures has become quite common in current scientific work, these issues are not typically addressed by high school curricula. In line with current definitions of scientific literacy (e.g., OECD/PISA, 2003) we believe that it is important to expose students to synthetic aspects of the scientific process, in addition to the more prevalent analytical aspects. However, by this we do not mean that students should be taught explicitly how to conduct a meta-analysis or

how to compute effect sizes (i.e., how to "do science", Millar & Osborne; 1998), since this procedural knowledge is only relevant for a small minority of the students who will become scientists in the future. Instead, our objective was to confront students with situations which require data synthesis, and lead them to articulate a solution, using an inquiry-based approach. Specifically, we chose to focus on synthesis in the context of graph comprehension (Bertin, 1983) in a process we refer to as *graph meta-analysis*.

Graphs are central communication devices in most empirical reports, especially in science but in other contexts as well. Non-scientists encounter graphs on a daily basis at work, in the popular media and the internet, even in advertisements. We use the data represented by these graphs in order to draw conclusions and make decisions. We may use a graph to choose which cereal brand to buy, and we may use another graph to decide whether or not to spill sewage into the river. Not surprisingly, graph interpretation and production skills are emphasized in national science standards (NRC, 1996). However, several studies have shown, several studies have shown that full competence in reading and producing graphs is not achieved even by college and university graduates (Bowen, Roth, & McGinn, 1999; Leinhardt, Zaslavsky, & Stein, 1990). Bowen and Roth (2005) found that pre-service teachers, most of whom had a BSc degree, lacked basic skills in graph interpretation, and reached the sad conclusion that "preservice teachers do not seem to be ready to teach data collection and analysis in the way suggested by reform documents." These findings highlighted the need for concerted instructional attention on graphic literacy skills (di Sessa et al., 1991; Shah & Hoeffner, 2002). If making sense of a single graph is a difficult task, then having to glean information from a comparative synthesis of multiple graphs is even more challenging. This activity, which we refer to as *graph meta-analysis*, is a common feature in the work of scientists (and other professionals) when they analyze their own data or when they review data presented by others. A similar challenge is faced by citizens who encounter graphs when they make decisions about science-related issues based on information that they garner from news reports, web searches or other similar sources.

In order to present several graph comprehension tasks within a realistic scenario, we designed a web-based learning environment (LE) using the STOCHASMOS (Kyza & Constantinou, 2007) platform. The topic of the environment was "*How can we choose the best smoking cessation aid?*" This environment required students to compare four pharmacological smoking cessation treatments using data (graphs) modified from recently published scientific journal articles. This report focuses on a specific task that required students to synthesize data from two line graphs, in order to rank the treatments by their efficiency, measured as abstinence from smoking. Each graph contained data from a different clinical study, in which *only 2 or 3* treatments were compared, in addition to a placebo control group. Thus, the overall ranking of *four* available treatments required a process of meta-analysis, involving measures of effect size.

Our research questions were: (1) Will high-school students be able to solve graph synthesis tasks correctly, and if not, what will be their difficulties? (2) Can an inquiry activity serve as an effective tool for teaching students to handle such tasks? (3) Can elements in the design of the inquiry environment effectively fill in the role of the teacher and serve as learning scaffolds? (4) Is there a critical role for the teacher in such learning activities?

METHODS

A first version of the Nicotine Addiction LE was tested in a pilot study in one 10th grade class from a private school in a lower-middle SES Arab town (N=35). The revised version was tested the in two Israeli 10th grade classes and one Cypriot 11th grade class. One Israeli class was from the same Arabic-speaking school (class Q, N=22) and the other from a

public school in a high SES Jewish suburb in central Israel (class R, N=16). The Cypriot class was from a high SES Greek-speaking school (class C, N=19). Students worked individually (class Q) or in groups of 2-3 students each. Only 49 students completed pre- and post-enactment individual assessment questionnaires. Two out of the three teacher participants (teachers of classes Q & C) were members of the Israeli and Cypriot development teams. We collected a variety of both process and pre/post data. Pertinent to the present report were the written responses to the "templates" (worksheets) in the computerized workspace, and responses on pre/postests. The pre/post-tests (two counterbalanced versions) included items on graph reading skills (some from PISA), items on conceptual knowledge about nicotine addiction and the use of control groups in clinical experiments, as well as items focusing specifically on graph synthesis.

RESULTS

We initially addressed these questions through a pilot study that presented students with the synthesis task, but with minimal scaffolding. Not surprisingly, the participants of the pilot study found the overall investigation very challenging and frustrating. Out of the whole class, only 11 pairs completed the synthesis task. None of the pairs ranked the medications correctly.Some of the specific challenges faced by students included: (a) Focusing on specific features of data in the line graph, e.g., differences between short-range and long-range effects of each treatment (8 out of 11 pairs); (b) Understanding the implication of different operationalizations for the same variable (all 11 pairs); and (c) Understanding the need to consider effect size (all 11 pairs). The teacher tried to provide scaffolding (Tabak, 2004) that was not provided by the computerized environment, through discussions with individual groups while they were working on their investigation, and through the asynchronous feedback notes that attach to the students' workspace. These mediations were not enough, so the teacher also held an impromptu whole class discussion that delved deeper into these issues. Obviously, the challenge for students became a challenge for the teacher. This challenge is amplified in settings where students work in small groups, each of which faces different obstacles in different time points, a situation that required the teacher to jump from one group to the other while other groups waited for their turn and sometimes lost their focus on the task and used the access to the internet for off-task activity. It is not surprising therefore that the teacher of the pilot class was exhausted at the end of each class, and this also affected her motivation to provide asynchronous feedback.

Following the results of the pilot study, we modified the contents of the LE. We added an introductory unit on placebo effects and control groups in clinical trials using a whole class discussion of case examples, and added prompting questions and hints in the text that accompanies the graphs in the LE. We made the graph representations easier to compare. Finally, we added special "synthesis templates" in the students' computerized workspace that included questions designed to scaffold the analysis and synthesis of these graphs.
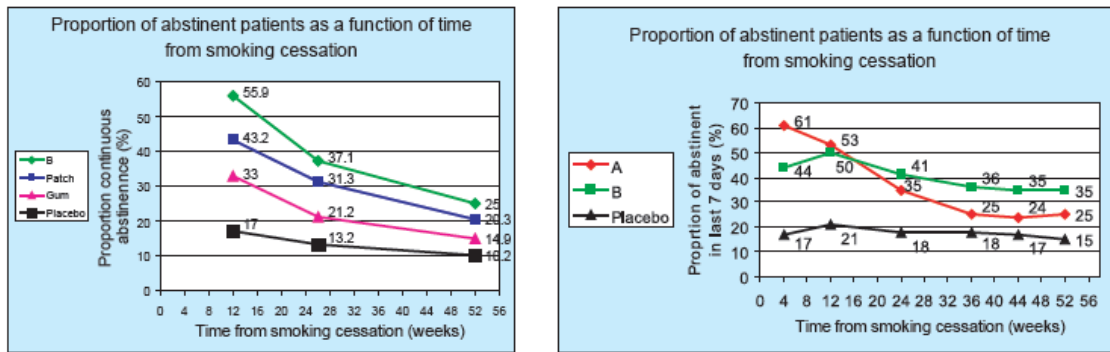
Figure 1: Graph synthesis task stimuli, following redesign

In contrast with the pilot study, most of the students ranked the medications correctly (58.3% compared to 0%). This difference was statistically significant (χ^2=10.69; p=0.001, Fisher's exact test). In class C, most of the teams did not complete the analysis of the smoking abstinence graphs due to time constraints, with the exception of two teams who proceeded ahead of their class but did not use the special the synthesis templates and, as expected, did not rank the treatments correctly. The highest frequency of correct ranking (85.7%) was observed in class Q, which was taught by the same teacher who taught the class of the pilot study. This teacher reported during the intervention that class Q was weaker than the pilot class, and its average grades in biology were significantly lower. Therefore it seems that differences in students' aptitude could not explain the differences between the pilot's results and those of the revised environment.

We also examined the arguments given by students to support their ranking. Even following the redesign of the environment, some students relied on the raw abstinence rates, and were unaware of the need to compute effect sizes, as can be seen in the following justification:

> "As we can see in the two graphs, the most efficient medication is B, because its results are the best, and the placebos in both graphs have the lowest results. We could compare them and therefore we merged the results. Medication A is ranked 2nd because in the other graph it is better".

Other students correctly justified their ranking by explaining how they computed the effect size:

> "I computed for each medication separately, according to the ratio between it and the placebo. I combined the results of the 1st and 2nd graphs, and the [medication] which got the highest ratio got the highest rank".

This justification was sometimes phrased with elaborate reference to the computation of ratios:

> "The computation principle: for every medication in the first part [=graph],divide the result at the end [=52 weeks] and divide it by the placebo. For example, medication B: 25/10=2.5. In the second part, divide by 15 instead of 10".

Some students understood that they had to compute a treatment to placebo ratio but apparently did not fully understand the meaning and utility of the result. For example, 4 students out of 14 from class Q computed the risk ratios of treatment B for the two studies, and then summed the result:

> "[For medication B] in the 1st table the ratio is 2.5 and in the 2nd table the ratio is 2.3, so the result is 4.8. The other ratios are computed as done for

treatment B. At the end it is clear that treatment B is the best, with a ratio of 4.8 and the gum is the worst ratio – 1.5".

In order to quantify the quality of the justifications and compare between students' responses for the pilot stimuli and revised stimuli, we defined a scoring scheme and used it to score the justifications on a scale ranging from 0 to 10 (inter-rater reliability: 0.86 for pilot data, >0.9 for data following redesign). These scores indicated an improvement in the quality of arguments from an average of 1.45 (SD=0.80) to 3.79 (2.39). This difference was statistically significant (t-test, t=4.287, p<0.001).

There was more than a two-fold post- to pre-test increase in students' response to the graph synthesis question. But, these results still indicate that graph synthesis is a very challenging task, because even after the addition of specific instructional scaffolds only 36.7% of the students answered the posttest graph synthesis question correctly (compared to 16.3%). Similarly, we see advances, but not broad changes, in students' understanding of the synthesis process through their free-form responses explaining their solutions. We quantified the quality of students' justifications, and used a mixed design repeated measures ANOVA to test changes in justification quality. The main effect of time (pre/post intervention) was statistically significant ($F_{(1)}$=27.2, p<0.001). However, there was also a significant main effect of version order ($F_{(1)}$=8.29 , p<0.01) and a significant interaction between time and version order ($F_{(1)}$=15.02 , p<0.01). These effects are related to the fact that one version of the synthesis questions included an additional challenge for students, since it referred to an adverse (negative) effect of two medical treatments compared to placebo control. In such cases, the treatment with the larger effect size (i.e., treatment effect divided by control effect) should be considered worse than the treatment with the smaller effect size.

In order to assess whether the intervention improved students' conceptual knowledge about control groups in medical research, we used three multiple choice items in each version of the pre/post assessment battery, for two of which students were also required to justify their choice. Students showed an improvement from pre-intervention to post-intervention, from 37.4 (SD=20.3) to 48.2 (28.1) on a scale from 0 to 100 (t=2.51, 48 dof, p<0.05), but still did not internalize some of the central messages of the unit on control groups and placebo effects. For example, when asked about a case in which a treatment group was tested against a no-treatment control group, none of the students claimed that the observed effect may be solely due to a placebo effect. A repeated-measures ANOVA did not reveal any significant main effects of class and version order, or any significant interactions.

In order to assess whether the LE improves graph reading skills, we used two PISA tasks that involved graph reading but were not related in content to our LE (Greenhouse effect, task S114 and stickleback behavior, task S433). These tasks were included in the pre/post assessments of classes Q & R. Half of the students received the Greenhouse task prior to the enactment and the stickleback behavior task following the enactment, and the other half received the stimuli in reversed order. The answers were scored according to "Take the Test: Sample questions from OECD's PISA assessments" (OECD, 2009). Out of a possible score of 100 points, students improved from 41.96 (SD=30.47) to 58.93 (24.73). A paired t-test showed a significant difference between pre- and post-test (t=2.37, p<0.05). A repeated measures analysis also revealed a significant interaction with version order, indicating that the Stickleback assignment was more challenging than the Greenhouse.

CONCLUSIONS AND IMPLICATIONS

In conclusion, we are encouraged by our initial results that show that we have problematized the issue of graph synthesis for students. They recognize that one cannot simply aggregate disparate graphs without some form of adjustment. However, there is still much room for increasing students' understanding of the problems associated with simple

aggregation, and with the specific procedures required for synthesizing graphs. The curricular and computer-based scaffolds we provided improved student learning, but these do not seem to be sufficient for broader and deeper learning gains. We hope that as a first step, our work will serve to include graph synthesis as an important part of the agenda for cultivating scientific literacy. In addition, we continue to explore how to scaffold and foster these skills, and how to integrate computer-based and teacher-provided scaffolds (Tabak, 2004).

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ANALYSIS OF ELECTROCHEMICAL CELLS PROCESSES SIMULATIONS. STUDENTS' POINTS OF VIEW.

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Abstract: We present a didactic and epistemological survey on the role and the relevance of the simulation in the understanding-modeling by the students of the working of the electro-chemical cells in closed circuit. Our step associates two approaches:
- on the one hand, an analysis of didactic and epistemological point of view of two applets of simulation of the electric conduction in an electro-chemical cell in closed circuit. One applet is conceived for teaching in Secondary school, the other for the university one.
- on the other hand, a semi-directive interview with students in the Upper Grade of Scientific Secondary School (France, 17-18 years old) explores both the observation of these applets, and the circulation of the carriers of loads and the selective drivers during the functioning of the cell.

We will debate about the didactic and epistemological relevance of the analyzed simulations that somehow seem to exceed the concrete experience, and to make the mechanisms of electro-chemical conductions "visible"/obvious to students.

Keywords: Electrochemical cell, electrical conduction, modeling, simulation.

BACKGROUND, FRAMEWORK, AND PURPOSE

Institutional context and theoretical frame

In the general education of physical sciences, it is usual to make reference to objects of the students' environment such as the electrochemical cells. Then electrochemical cell and their modeling are part of the 2002 French Chemical curriculum of Scientific Secondary School Upper Grade students (17-18 years old). The official instructions (BO) emphasize how to design effective model-based learning environments that actively involve students in their learning process. They recommend "*to simulate* [Computer simulation] *the evolution of the electrical behavior of a cell towards its balance state (discharge) by realizing many progress states of the system evolution corresponding to increasing values of the progress of reaction*". It is in this institutional framework that the present study is registered.

Besides, the choice to use computer animation justifies itself in theory as follows: the approach of real life situations, in this case electrochemical cells, to enable students understand better, rests on the following principles: understand the functioning of a given phenomenological situation, is to represent it by a model (Halbwachs, on 1974). Modeling is the construction of a system of signs which substitutes itself to the physical situation in question and allows making operations of interpretation and forecasting (ibid). Besides, Peirce (1978), in its triadique conception of the sign, puts the iconic sign in the heart of the scientific work of conceptualisation and modeling. The physical situation in electrochemistry involves two interdependent dynamic phenomena (ohmic conduction and electrolytic conduction) and

not only static structural aspects. So, the simulation of the phenomenon seems the most appropriate way of "materializing" numerically the system of signs (the model) as mobile iconic signs. It therefore ensures a function of semiotic imitation (Schaeffer, on 1999) of the imagined functioning of the electrochemical cells.

By gross simplification, we can say that simulation (computer animation) is a scrolling through the help of a computer of several images different from the plan (system of signs) of the electrochemical cells presented one after the other at different but very close instances like a cartoon. It gives the impression of a continuous progress in time of the functioning of the cell. This representational function also ensures (at least during the first steps of the approach of the phenomenon), a flashback towards its origin (the cell, the original, the imitated) (ibid). The question of the mastery of the parameters of simulation does not arise here: the students do not have the possibility to vary neither concentration, nor speed of the charge carriers, nor resistance in the circuit…). The simulation thus enables to see an invisible phenomenon with the naked eye and contributes, therefore, in its modeling. This capacity to be able to produce something to see rests in the fact that it operates a semiotic substitution of a system of signs (grade-related and symbolic) (Peirce, on 1978; Halbwachs (1974)) in the experimental, empirical device.

We suggest analyzing in what, and in which measure, the use of computer animation of an electrochemical cells can facilitate students in developing deep understanding of electrochemical concepts, and the modeling process itself in order to motivate them to learn more about chemistry.

Everyday cell versus the didactic cell

In the case of electrochemistry, where the object of study is mainly electrochemical cells, the student is found in front of a "didactic" object (fig.2a, fig.2b) different in all aspects from the view of the "everyday" object (fig.1). So, for the student, the link between both objects (didactic and everyday) is not immediate.

Indeed, for a student situated spontaneously (and often) at the empirical world (immediate perception), there is not common point between these two objects:

-       The one of everyday use, is compact, in a single block (very fortunately for the convenience of its use in the everyday life), which the student ignores not only the constitution, before any lessons, but also and especially the functioning principle. This object, very practical, remains thus a real "black box", somewhere mysterious. Furthermore, it can appear under different geometrical forms, sizes and capacities, without necessarily having a proportional relationship between these three characteristics (fig.1).

Fig 1. picture of every day cell

Fig 2a. Picture of didactic cell with porous wall.

Fig 2b. Picture of didactic cell with salt bridge jonction.

The other object called didactic, appears under two different forms: one constitutes of two separate vases either by the porosity of one of the vases which would then be placed in the other one, or by a porous wall, common to both vases (fig.2a). The other one constitutes of two separated beakers, a beaker containing a solution (generally solution of metallic ions (Mn^+) into which a metallic blade is inserted (the metal M), the other beaker similar to the first one, but with a different metal. For the student eyes, both beakers are interconnected by a kind of U "tube", installed upside down (!) in which there is a third solution again different from the two others (and which surprisingly could remain inside by its own without flowing in the beakers)

Each one of these didactic cells (figure 2a, 2b) is a type of macroscopic analogous model of everyday cells (figure 1); these imitations which permit to explicit its constitution and to ease understanding. In this way, the cell of fig.2b performs the same function as the cell of fig.2a, especially concerning electroneutrality. Unfortunately, they are not always presented as such. As we are going to explicit below, several researches have documented student's misconceptions concerning electrochemistry even after having received lessons (See bibliography). Most of them promote the use of simulation to build a model of the electrochemical cells. However, they have not implemented them in the same manner. There is therefore a scope to push the modeling process to a microscopic level to understand the functioning of a cell.

Difficulties in electrochemistry, and search of a remedy

The difficulties of students to understand electrochemical phenomena generally and the conduction of electric current in electrochemical cells in particular were the object of numerous research works all around the world. Several types of approaches were designed to try to understand the origins of these difficulties and to resolve them:

Garnett and Treagust (1992a, 1992b) identified indicators on the "reasoning" of students in electrochemistry by interviewing 32 students at the end of the high school cycle sector, after being taught electrochemistry. They think that "*in a solution, the electric current is due to a flow of electrons*", that "*electrons in solution are attracted by ions, and hence they move by passing from an ion to another*". Besides the problems which they have about the electric conduction, some students mistake electrodes, their polarity, as well as the name of the ions which are referred to them and the sign of the electric charge carried by them. These results were confirmed by Ogude and Bradley (on 1992, 1994) through a multiple choice question (MCQ) with 6900 students. These researches did not propose alternative didactic situations enabling to improve these conceptions and to develop them towards a satisfactory state of knowledge of the functioning of the electrochemical cell.

Based on the conceptions elaborated through previous works, Bouraoui and Chastrette (1999) led a study whose objective was to propose a remedy. For that purpose, they conducted a comparative study in Tunisia and in France on 83 high school students (16-18 years) and university students (in their second academic year in sciences) on these same phenomena. They displayed in front of the students the experimental assembly of an electrochemical cell during its functioning state, accompanied with its conventional diagram, making the link between both (a fast display of the model and the modeled object). The result of the questionnaire administered after the experiment is not convincing, and does not present a considerable evolution of the conceptions of the students to whom a misuse of the "electronic model" of conduction persists.

The limitation of the effect of this approach on the conceptions of students can be predictable. Indeed, on one hand, the diagram is already a part of the model (an iconic sign of the model), whilst its building rests with the student. Presenting students a complete diagram, is to postulate them the model and to invite them to make "the big step", difficult to realize for a learner suffering "handicaps" identified in the aforesaid researches. On the other hand, the diagram is congealed by nature; its construction does not always render "visible" a dynamic phenomenon, such as the movement of electrons and ions in the cell. We think on the contrary that it would be more relevant to make the building of the functioning cell diagram on the basis of the realized experiments, otherwise the diagram and the experimental set up would remain two worlds apart, which do not communicate between them. The multiplicity, and multiplication, of registers constitute a fundamental didactic variable in the elaboration of the models, provided that the student is involved in their construction.

Sanger and Greenbowe (on 1997, 2000), in a remedial didactic approach, opted for a display of the motionless diagram on one hand, and a dynamic numerical representation which they called computer simulation on the other hand. This experiment was done in two steps: first a display of computer simulation on the flow of electrons in metals, and then the flow of ions in aqueous solutions and the salt bridge. By proceeding in this manner, they thought that this division in time would be effective by allowing the students to focus on a single type of electric conduction once at the time to understand it better. Indeed, the students seem to have better understood the phenomenon of conduction in every type of conductor. This encouraging result shows concretely that simulation helps in the modeling of phenomena governing the functioning of an electrochemical cell. However, from their confession, these authors were a little bit surprised by the high number of still indecisive students, who manifested difficulties in associating both parts in the same continuous circuit, and thinking that electrons can flow freely in solution. If they suspect the quality of the simulation, and the short period of its display in front of the students, they do not seem to question the sequential presentation of the simulation. However, it can be a very interesting track to explore.

Besides, the eventuality of an additional difficulty which would be due to the junction by salt bridge (fig.2b) does not seem to have been explored in these researches, that is, pondering was not done on the relevance of a "model" of a cell with salt bridge in relation to a model where the junction is made by a porous wall. It is another question than we suggest dealing with in this contribution.

Following the continuity of these researches, our approach emits two main hypotheses:

The first one concerns exactly the purpose of the integrated character of the simulation of the functioning of cells, by opposition to the separated approach used by Sanger and Greenbowe (on 1997, 2000). It would be advisable then to select the most appropriate simulation for that purpose.

- The second concerns the comparison of the didactic relevance compared between both types of Daniel cells: that with the porous wall junction and that with the salt bridge junction. The second can be shown as an analogical model showing more of the flow of the charge carriers in the salt bridge.

Equipments and methods

Our equipments are two computer simulations on the functioning of cells, on one hand, and a paper questionnaire and pencil on the other hand. We were able to find, on the internet, two simulations which filled both the following conditions: (1) one of them corresponds to the didactic cell fig.2a. It is a simulation proposed by a high school teacher named Bruno HAAS (that we have indicated by the code SBH), and (2) the other one corresponds to the didactic cell fig.2b. It is a simulation proposed by university lecturers on the website of the on-line university (code: SUL).

Besides the correspondence with both didactic cells, these simulations satisfy the conditions of acceptability and accessibility developed by Tribollet and Fatet (2003) about the analysis of the numeric resources (of popularization or didactics) available on the internet.

For the experimentation, 22 students in the final year of scientific high school (17-18 years, Fr), having already followed lessons on cells with regard to the official curriculum were chosen on a voluntary basis. They thus saw the device in Fig.2b at least once. We submitted them to a pre test questionnaire, before they began viewing the simulations. Then, they were invited to watch freely on computer the simulations in question. And finally, we submitted them to the same questionnaire as the pretest, followed by a semi-directive interview on the use (their preference, impressions) on both simulations. The questionnaire is a multiple choice questions (MCQ) type. We shall explain here only the results obtained according to the abstract criteria of order and modeling. Also, we shall see the way in which the simulations were perceived by the students, as well as the effects on their reasoning.

SOME RESULTS AND DISCUSSION

According to our corpus, our results are two kinds: an analysis of the simulations in question, on one hand, and an analysis of the students' answer on the other hand.

Analysis of the SBH and SUL simulations

If from the chemical point of view the electrochemical phenomenon remains the same in both types of cells (fig.2a, and fig.2b), the presence of the salt bridge seems better highlight the half-cells by separating them in space. This could, from this point of view, facilitate the understanding of the functioning of the cell.

Besides we compared the real functioning of these two cells, and verified that the presence of the salt bridge presents a major experimental inconvenience, namely the sharp increase of the internal resistance of the cell (300 times superior to that of the cell with junction by porous wall).

The SBH simulation

The SBH is elaborated in a single sequence of 36 seconds. It starts on an unanimated global plan and offers (to the chemist or the warned student) an overview of all the representative iconic signs of the functional structure of the cell (Fig.3). We also see that there is a single electron involved which flows outside the ohmic driver, parallel to it. It constitutes an abnormality in its imitative function of this conduction, not in what it badly sends backwards towards the imitated original, but in what it sends forward towards its effects (Schaeffer, on 1999) on the conceptualization of electroneutrality. Furthermore, this simulation is accompanied with no other semiotic register which could help the student to follow it without getting confused of the electric conduction.

Fig 3 Picture of SBH computer simulation

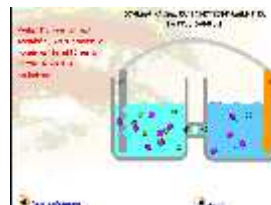Fig 4 Picture of SUL computer simulation

Fig 5 Picture of SUL computer simulation showing the flow of electric charges

This simulation (fig. 4 and 5) includes 55 sequences (among which 26 are animated), in 3 minutes and 23 seconds, associating observable macroscopic, such as the increase of the mass of the copper plate, the decrease of that of zinc, or still the color change of solutions, and the microscopic aspects (interpretations of the first ones) for which it is fundamentally intended.

We can blame this simulation for the absence of the interactive character of conceiving and building, which enables the student to practice and verify his own experiences.

Analysis of students' answers

The questionnaire used here is inspired by the questions formulated in the works previously quoted.

The pre-test gives, with some degree of accuracy, similar results to the researches of referenced works. For example, 40% of the students show difficulties to understand the flow of electrons and ions respectively in the ohmic conductors and the electrolytic conductors of the cell. Although the students already had a lesson on this part of their program, this results show the significance of the difficulties of students to identify the charge carriers and their respective flow sites when the cell debits. The teaching seems to have not targeted these difficulties to develop them.

It seems the free viewing of the simulation enabled to obtain a very encouraging result during post test (same questions with pre test). 80% of the students in TS (but not 100%) seem to have mastered the flow sites of the different charge carriers of electric current.

Questioned about the simulation which they prefer, the students choose without hesitation the SBH simulation. In the question "why do you choose the cell with salt bridge?" they argued that "it is clearer, we see better… the other one [that with the porous wall] is much too complicated. It takes a lot of time". Indeed, the SBH asks them for less concentration efforts because it lasts less than a minute, in a single sequence, especially since it seems to them that it presents exactly the same thing as the SUL, which is not the case. The students seem to disregard details which seem to them as secondary, such as the step of construction of the cell, and the progress of the underlying chemical reaction, in reference to the transformations of the material so simulated. Besides we could wonder if this preference is not influenced by the nature of the teaching they have already received on this subject, and where the cell with junction by salt bridge is the didactic example in the curriculum.

CONCLUSION

If the computer simulation plays an important role in the modeling of the physical situations, such as the functioning of the electrochemical cell, nevertheless its status at high school is one of a means which does not have to be confused with an objective (the modeling). The students do not participate in the construction of the simulation, which is an intellectual work of quite a

different nature which could enable understand what distinguishes a model from reality of reference on one hand, and the simulation itself on the other hand.

The results of the post test are to be dealt with carefully, especially due to the pre test (which took place after the teaching of this theme) because the questionnaire was administered just after viewing the simulations. The students still thus had fresh memories filled with the images of the simulation.

But the purpose of the simulation and its effect on the development of students' conceptions remains undeniable. The students' preference of the SBH lets us think that they do not make reference only to the scientific knowledge to answer the questions. It also shows the importance of the ergonomic criteria, and other (time, the number of sequences, the neatness of the images, the size of the images, and the simplicity of the images) in the construction of a didactically effective and attractive simulation.

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A RELATIONAL MODEL OF THE LEXICON TO DESCRIBE AND ANALYSE ECOLOGICAL CONTENTS IN PRIMARY SCHOOL TEXTBOOKS

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Abstract: The importance of ecological knowledge since childhood has been well stressed out in letterature concerning pro-environmental attitudes. Although some authors underline the key role of school textbooks in the process of scientific knowledge construction, the ecological contents in schools textbooks have been poorly studied. The aim of the present work is to project a computational procedure and to develop a model of primary school textbook lexicon to describe the structural organization of the document and to detect the weight of Ecology. The computational procedure has been projected to collect, to order to archive and lastly to process the data. To test the methodology, one of the most used italian textbooks series has been worked out. The model that has been obtained is a relational one. The relational models are, infact, flexible and interactive, and allow to explore the organization of the textbooks and to detect the weight of the contents. Indeed, the model provides a representation of the semantic structure of the document so that it can be aligned with other lexical resources and ecological domain ontologies.

Keywords: Computational lexicon, Ecology, Ontology, Primary School textbook, Relational model.

INTRODUCTION

It is important to encourage the study of Ecology in the early school years, because increasing environmental knowledge may result in more positive pro-environmental attitudes (Prokop & Tunnicliffe, 2008). Many Authors underline the importance of textbooks in science teaching in primary school (Chiappetta, Fillman & Sethna, 1991; Korfiatis, Stamou & Paraskevopoulos, 2004) for both teachers (Stern & Roseman, 2004) and students (Caravita, Margnelli, Valente & Luzi, 2007; Caravita et al., 2008). However, some Authors (Korfiatis et al., 2004; Caravita et al. 2007; Gambini, Pezzotti & Broglia, 2008) point out that Ecology is poorly represented in schools textbooks. During primary education, pupils are expected to develop increasingly more complex and systemic ideas about the living beings and their environment. Particularly, the italian curriculum for primary fifth grade includes aspects concerning biological systems and environmental systems such as ecosystems, their biotic and abiotic characteristics, the way human being can protect environment (Ministero della Pubblica Istruzione, 2007). It is than interesting to assess the real alignment of ecological contents of textbook and italian school curriculum.

The content analysis of textual documents require the use of methods to single out the useful features found in the text (Feldman & Sanger, 2007). Moreover, the development of a model is a necessary process when working in computer environment, since just a model enables to maintain the dynamism inherent in the linguistic-textual system of a document (Orlandi, 2010).

The relational approach tries to make explicit the structural organization of a document, which is implicit in models of other approaches, and describes how the terms extracted from

texts are related to each other (Evens, 1988). Furthermore, as the conceptualization of basic ecological concepts and processes is an essential requirement in order to come to understand more complex ecological subjects of study, this approach allows to assess the exposure of children to ecological knowledge during the all five years of primary school. For this reason the content analysis of textual documents requires a flexible representation models for the assessment of contents of interest through the texts (Feldman & Sanger, 2007) as through the school time.

PURPOSE

The aim of the present work is to project a computational procedure and to develop a model of primary school textbook lexicon to describe the structural organization of the document and to detect the weight of Ecology.

MATERIAL AND METHOD

In order to assess the procedure, it has been processed one of the most used italian textbooks series, published by Giunti. Five books, one for each school grade have been analyzed, considering Geography, History and Science sections, for a total of 661 pages.
Each textbook is organized into well distinct and hierarchically nested structural parts (hereafter Visual Blocks or VBs). Main VBs are represented by thematic sections, each divided into chapters, and these subdivided into paragraphs that are associated with the paratext VBs, such as boxes, pictures and insets. The paratext is important from the standpoint of learning as they give the student the opportunity to study in-depth and to check understanding. Every VB is thematically homogeneous. It is also important to stress that the terms of subject content, considered important by the Author (hereafter Relevant Terms or RTs) are highlighted by special fonts in both text and schemes. Each textbooks series results from editorial decisions on the layout and organization of information. Despite this diversity, it is possible to trace the variety of VBs of the different textbooks series at a general VB types taxonomy. The detection of RTs is implemented in the model as the representation of the content of a textbook. The VB types taxonomy is intended to provide criteria for the classification of VBs. The lexical relations between the RTs contained in VBs are inferred based on the hierarchical relationships between VBs.
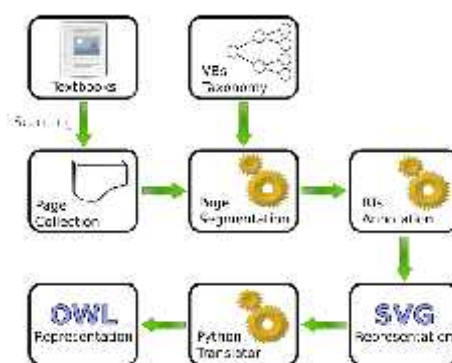

Figure 1. The computational process.

The Figure 1 illustrates a diagram representative of the computational procedure. The process is interactive and requires the intervention of a human agent. The book pages are scanned and raster images produced are collected in an archive. Each page is split up into constituent VBs

through visual segmentation. To this end, each VB is recognized by its distinctive characteristics and classified with reference to the VB types taxonomy. Every VB identified is annotated with the RTs that are contained in it.

Page segmentation and RTs annotation are performed with a vector graphics editor like Inkscape (http://inkscape.org), which is based on the W3C SVG, derived from the XML. A page raster image is imported into the software user interface, and every VB is bounded by a polygon that the software automatically translates into XML. Then, using the XML editor integrated in Inkscape, the VBs are annotated typing the respective RTs in. The lexical relation between the terms are defined with the RTs annotation. The RTs of a higher order VB subsume the RTs of the lower order VBs. This rule generates a tree structure of the RTs of the page. The annotated SVG file is then processed with an *ad hoc* Python (http://www.python.org) script, which implements an XML parser, which can combine RTs trees of different pages and can optionally translates outcomes in OWL format, a standard ontology modelling language of the World WideWeb Consortium (http://www.w3.org/).

The combination of different RTs trees is done through identification and connection of equal RTs. The result is a directed graph where each node is represented by a distinctive RT and edges depend on how the pages have been segmented. This structure is analyzed using measures rooted in graph theory (Bang-Jensen & Gutin, 2007). With these measures, the general organization of each graph and the topological properties of individual concepts are detected.

RESULTS

The graph obtained consists in 2009 nodes and 4816 edges and has a diameter of 8 connections.

Ecology, for example, explicitly appears only once and has a node degree of 1. Moreover, *Ecology* has an eccentricity of 7 and a diameter of 8.

Figure 2 shows a RTs tree resulting from segmentation process of a page in the Giunti Scuola textbooks series.
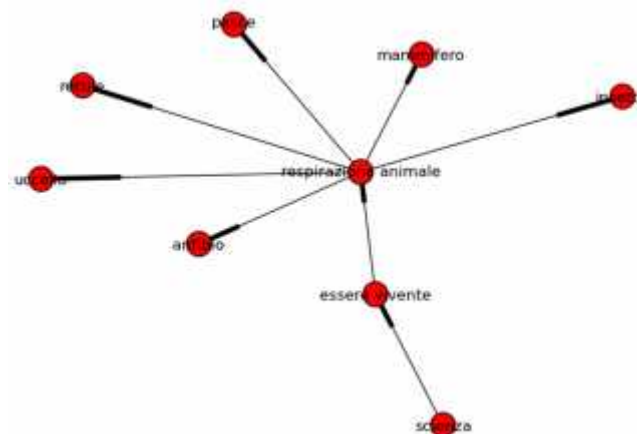
Figure 2. An RTs tree.

Figure 3 shows the graph obtained by the combination of the RTs tree of Figure 2 with the RTs tree of the following page. The two original trees have in common the RTs of the section title, "scienza" (*science*), the chapter title, "essere vivente" (*living being*), and a group of terms including "scheletro" (*skeleton*), "invertebrato" (*invertebrate*), etc.
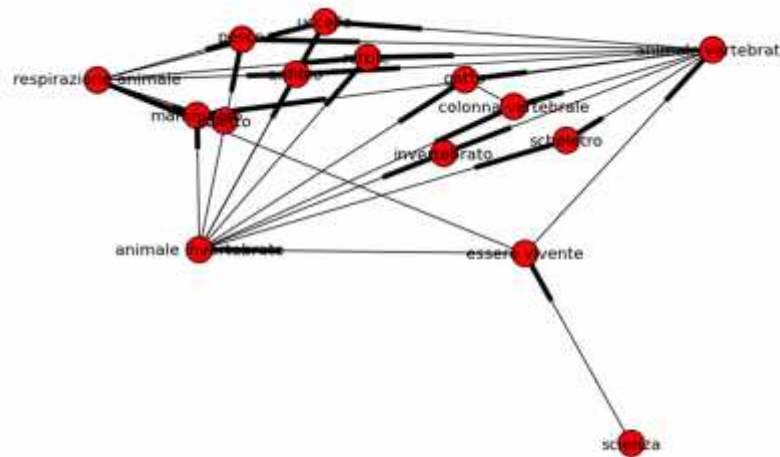
Figure 3. Graph resulting from the combination of two RTs tree .

Combining RTs trees sequentially and orderly, it is possible to analize the evolution of each graph measure with the flow of pages. For example, Figure 4 shows the evolution of graph diameter (by definition, the smallest of all shortest path lengths of the graph) resulting from the gradual combination of the pages, from the first page of first year textbook until the last page of the fifth year textbook. Similarly, Figure 5 illustrates the evolution of the eccentricity of the two terms "animale" (*animal*) and "pianta" (*plant*).
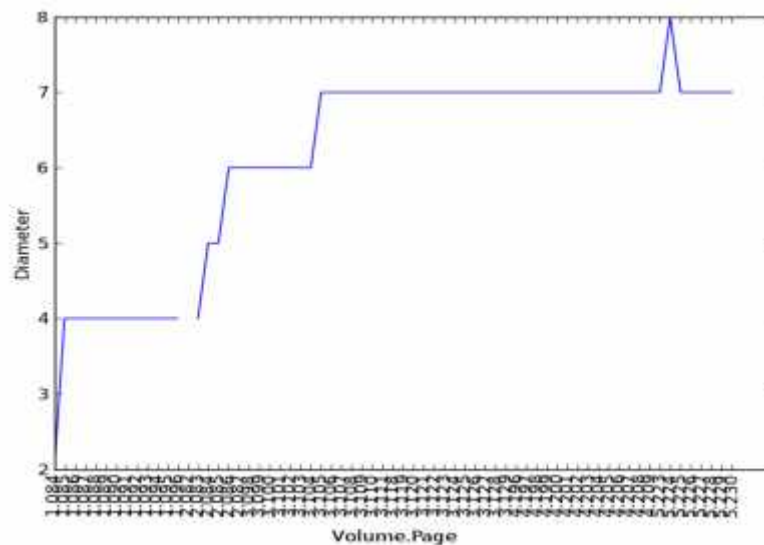
Figure 4. Graph diameter evolution.
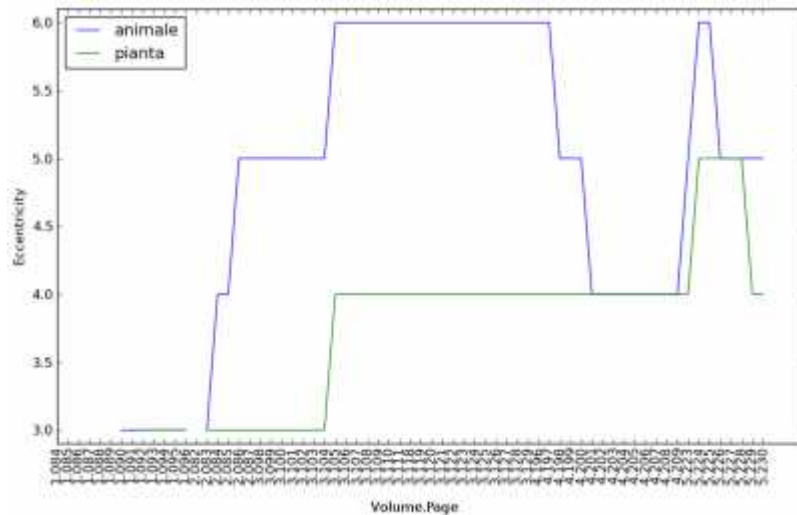
Figure 5. Evolution of eccentricities of the "animal" and "plant" nodes.

DISCUSSION AND CONCLUSION

The model seems to be suitable to describe the structural organization of the textbooks and to detect the weight of Ecology within them. Therefore, it allows to assess the children's exposure to ecological concepts during the five primary school years.

Furthermore, the analysis of the network at every stage of its evolution allows to evaluate when and how ecological concepts are introduced and their progressive differentiation. This offers interesting pedagogical interpretations analizing different disciplines presented into the same textbook and comparing different textbook series. The model is also flexible and can be aligned with ecological domain ontologies (Thiagarajan, Manjunath & Stomptner, 2008; Prèvot, Borgo & Oltramari, 2010) This will allow to measure the distances between the ecological contents detected and a more general ecological domain. Our current research is proceeding also forward the application of the relational model to obtain semantic relatedness measures that can be assessed in a pedagogical point of view.

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DEVELOPMENT AND EVALUATION OF A DIGITAL ENVIRONMENTAL LEARNING GAME FOR CHILDREN

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Abstract: This research described the development of the Vegetation Interaction Game, a new digital game on the theme of vegetation succession. An evaluation experiment targeting elementary school students was conducted in order to verify the efficacy of this game as a learning-aid tool. The results of the knowledge and understanding test, a survey on the degree of immersion and a survey on the user-friendliness of the interface revealed that this game (1) supported children in their knowledge acquisition and understanding of vegetation succession, (2) helped children become immersed, and (3) provided children with a user interface that could be understood easily.

BACKGROUND AND THEORETICAL FRAMEWORK

In science education, digital games have become one of the more effective learning tools. In such a learning environment, a learner can acquire scientific knowledge through the process of role-playing in the game. For example, simulation in a game can reveal the phenomena and processes of the microscopic motions of atoms and molecules, as well as macroscopic movements, and large temporal-scale phenomena.

Clark et al. (2009) reviewed preceding studies on digital learning-aid games in order to verify the efficacy of this game as a learning-aid tool. According to this review, major characteristics of such games included the players becoming immersed in the game by entering the character of the game, acquiring new knowledge as the game progresses, or applying the acquired knowledge as the game unfolds. Many digital games have been developed as learning aids in science education (for example, Barab & Dede, 2007; Collera, 2000; Dede, 2009). However, a game themed on vegetation succession in forests did not previously exist.

In this study, we developed a new digital game themed on vegetation succession. Vegetation succession

is a phenomenon wherein the numbers and types of plants in a forest undergo transition during a certain time period. This phenomenon occurs largely due to substantial disturbances such as tree cutting or landslides, and interactions between certain types of plants in the forest. It takes many years to complete one succession. A digital game themed on vegetation succession appears to be very useful for students to understand such large temporal-scale phenomena.

PURPOSE OF THE STUDY

The aim of this research was to develop the Vegetation Interaction Game, a new game themed on vegetation succession, and to evaluate its efficacy. This game employs the role-playing board game format where each player is represented by a token and the game progresses by advancing these tokens along the squares on the board. The player that advances his/her token the most wins the game. An evaluation experiment targeting elementary school students was conducted in order to verify the efficacy of this game. The following three questions were posed in this research:

(1)   Does the Vegetation Interaction Game support children in understanding vegetation succession?

(2)   Is the Vegetation Interaction Game something children can become immersed?

(3)   Is the interface of the Vegetation Interaction Game easy to understand for children?

DEVELOPMENT OF THE VEGETATION INTERACTION GAME

The Vegetation Interaction Game represents what a real vegetation succession looks like. A phytosociologist who is an expert on the Mt. Rokko area in the western Japan was the principal consultant of this game. Figure 1 shows the main window of the digital game. Six pieces represent six characteristic plants that grow in the Mt. Rokko region. The six plants include two early succession plants, Red small berry (*Rubus microphyllus* L. fil.) and Japanese Mallotus (*Mallotus japonicus* (Thunb. ex Murray) Mueller-Arg.); two middle succession plants, Red Pine (*Pinus densiflora* Sieb. et Zucc.) and Quercus oak (*Quercus serrata Thunb.* ex. Muuray); and two late succession plants, Longstalk holly (*Ilex pedunculosa* Miq.) and Castanopsis evergreen oak (*Castanopsis sieboldii* (Makino) Hatusima ex Yamazaki et Masiba). The central part of main window houses the following components of the game: a deck of event cards (Fig. 1-a) and a visualization screen to show vegetation succession according to the progress of the game (Fig. 1-b). Players can switch this vegetation succession visualization screen to show only one plant to focus on that plant.

If more than one piece takes the same position on the grid, the competitiveness for the light is either strong or poor between the plants; that is, the 'interaction' between the plants, as shown in Fig. 2. We set the event cards to correspond to types of disturbances that could possibly occur in the Mt. Rokko region. There are six such event cards: two large disturbances—tree cutting, landslide; two small

disturbances—wild boar and pine longicorn-nematode disease; and no disturbances—fair weather and rain. These events influence vegetation succession.

Six players can participate in any one game. Each player handles one piece. Players draw event cards, one at a time, by clicking the event cards in turn. When a plant piece advances ahead on the board grids, it implies that the plant is dominant in that particular environment. Each piece moves according to the number of grids that the current event card indicates or if there is an interaction between the plants. The game finishes when all event cards are drawn.
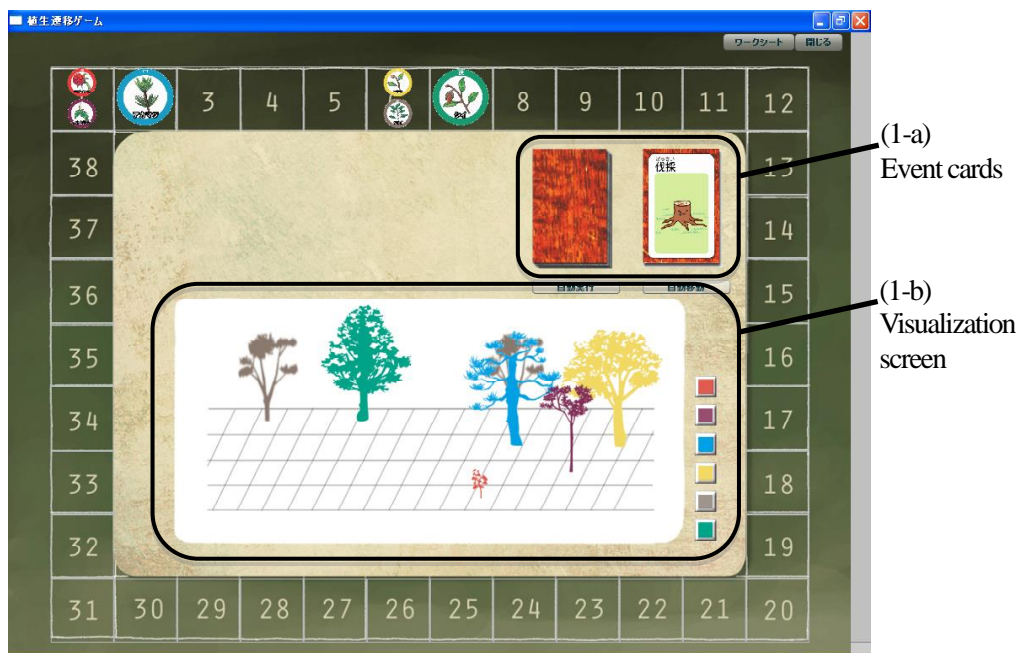
Fig 1. Main Window

Fig 2. Interaction between plants

EVALUATION OF THE GAME: RESEARCH DESIGN AND METHODOLOGY

Knowledge and understanding test

A knowledge and understanding test on the same topics was administered to 36 children before and after they played the game. The test consisted of a total of 18 questions on the understanding of 'influence of disturbances' and 'interaction among plants'; both the pre-test and the post-test were graded out of a maximum score of 18.

Survey on the degree of immersion

A survey on the degree of immersion was conducted using questionnaires targeting 36 children. There were a total of 16 questions and children were asked to choose one of four levels of responses for each question.

Survey on the degree of user-friendliness

A survey on the degree of user-friendliness targeted 17 randomly selected children. The two questions were 'was the visualization screen of the interface easy to understand?' and 'was the interaction among

plants easy to understand?' Approximately 10 minutes were spent on each child. In the analysis, the numbers of 'children who gave only positive answers,' 'children who gave both positive and negative answers,' 'children who gave only negative answers,' and 'children who did not answer' were counted for each question.

DATA ANALYSIS AND RESEARCH FINDINGS

Knowledge and understanding test

The average scores were 5.00 (standard deviation 2.63) for the pre-test, and 11.47 (standard deviation 2.31) for the post-test. Using the Wilcoxon signed-rank test, it was revealed that the post-test yielded significantly higher scores ($z=-5.14$, $p<.01$).

Survey on the degree of immersion

Table 1 shows the result of the survey on the degree of immersion. 'Definitely' and 'I think so' were considered positive answers, and 'Not really' and 'Definitely not' were considered negative answers. Fisher's exact test (1 by 2) was conducted in order to examine the answer trends. The results revealed that the number of positive answers exceeded the number of negative answers in every question .

Game Interview

  'Children who gave only positive answers' and other children were tallied and Fisher's exact test (1 by 2) was conducted in order to examine the answer trends of the children. The results revealed that the number of 'children who gave only positive answers' significantly exceeded the number of all other children.

Table 1. Results of survey on the degree of immersion

Questions	Definitely	I think so	Not really	Definitely not
1. The game was fun to play.[**]	35	1	0	0
2. I want to play the game again.[**]	32	3	1	0
3. I was immersed in playing the game.[**]	29	6	1	0
4. I was excited in playing the game.[**]	32	3	1	0
5. I felt like I was the plant.[**]	9	22	4	1
6. I understand the influence of disturbances well.[**]	17	18	1	0
7. I understand the interaction among the plants well. [**]	15	19	2	0
8. I watched the balance of power relationship between the plants when the interaction	28	7	1	0

happened. [**]			
9. I understand the power relationship between the plants immediately when the interaction happened. [**]	18	16	2	0
10. I thought a lot about the increase/decrease in the number of plants when the interaction happened. [**]	11	19	6	0
11. I discussed a lot with group members when the interaction happened. [*]	6	20	9	1
12. I watched the vegetation succession visualization screen during a game. [**]	27	7	2	0
13. I switched the vegetation succession visualization screen to show only my plants. [**]	20	7	6	3
14. I understand the increase/decrease in the number of plants immediately when I watch the vegetation succession visualization screen. [**]	25	9	2	0
15. I could imagine actual vegetation succession from the vegetation succession visualization screen. [**]	12	20	4	0
16. I discussed a lot with group members when I watched the vegetation succession visualization screen. [**]	9	23	4	0

$N=36$. [**]$p<.01$, [*]$p<.05$.

CONCLUSIONS AND IMPLICATIONS

This research was used to develop the Vegetation Interaction Game using vegetation succession as the theme. Further, a demonstration experiment was conducted at an elementary school in order to verify the efficacy of the game. Three tests/surveys concluded that the Vegetation Interaction Game, as a learning-aid tool for science education, possesses the digital-game characteristic of immersing the players in the game while supporting their knowledge acquisition and understanding of the scientific phenomenon of vegetation succession. Clark et al. (2009) mentioned that the effectiveness of digital games in supporting children's learning is that games have rules and goals that encourage children's becoming immersed in the game and simulations that accelerate children to imagine macro/microscopic, or large temporal-scale scientific phenomena. It can be said that the Vegetation Interaction Game developed in this study is effective in supporting children's learning of role-playing and visualization screens.

This research succeeded in developing a new digital game that supports science education, themed on an unprecedented topic of the scientific phenomenon known as vegetation succession. Vegetation

succession is a phenomenon where the species and number of dominating plants change within a certain forest environment. In this day and age, where harmonious coexistence of mankind and nature is a major goal, it is important to provide children the opportunity to understand and gain first-hand experience of the vegetation succession in forests through science education. The implication of this research is that digital games can be effective tools for supporting the learning of these types of phenomena.

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TRANSPOSITION OF A SCIENTIFIC TOOL INTO THE EDUCATIONAL WORLD:
THE CASE OF MOLECULAR VISUALIZATION

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Abstract: Molecular visualization (MV) software enable a user to view a molecular model via a computer. They are regularly used by researchers in biology in many ways and the willingness on the behalf of the institution was strong to very quickly integrate the MV software in biology education.

Our work here focuses on the transposition of a scientific tool, the MV software, in the educational world and specifically on their use with students. It is relevant to study their conception and use in the classroom because several studies have shown that they can improve the understanding of molecular concepts among learners.

In order to study this use, we employed three types of indirect approaches, analysis of the francophone web, analysis of textbooks from three editors since 1992 and analysis of interviews conducted with five French biology teachers who use MV software.

The results obtained by these three approaches converge and indicate that there has been the production of a scholar tool from a scientific tool. More specifically, we observe that almost only one software is used, some molecules related to this software and some activities designed using this software and these molecules. However these activities remain illustrative whereas one might have expected some of them to enhance an investigation posture. Furthermore, the origin and status of molecular models are not or very little explained. And this may lead the students to a misconception of the molecular models.

Keywords: Biology education, ICT, molecular model, use of molecular visualization software

BACKGROUND, FRAMEWORK, AND PURPOSE

In the teaching of biology, in the early 1990's, there was a willingness of the institution to be as close as possible to the scientific techniques developed in laboratories [Demounem 1992].

Our framework is based on the idea developed by Martinand (1989) that the academic discipline refers to social out of academic discipline defined as "social practical of references" and particularly scientific practice for science education. We are also study how the computerization of a discipline works, a field described by Linn in 2003.

Here we are going to investigate the result of the transposition of a scientific tool into the educational world. For that, we are going to focus on the case of molecular visualization (MV).

In the early 1950s, biologists realized the first models of biological macromolecules. Knowing the structure of these macromolecules represents a significant challenge given their small size, we understand it is necessary to use various experimental techniques (such as X-ray crystallography) to get information on the molecule and thus build up a model (see figure 1). The first models were visualized using large physical models (several meters). But it's in 1966 that Cyrus Levinthal and his team [Levinthal 66] realized the first MV through a computer. Subsequently, the software and computers have improved and, in 1993, *RasMol*, a MV software able to run on a personal computer, is put into the public domain which has brought this technology formerly restricted to a few research centers at the door (financially speaking) of all. For further details on the historic of MV, see Matz & Francoeur (2010).
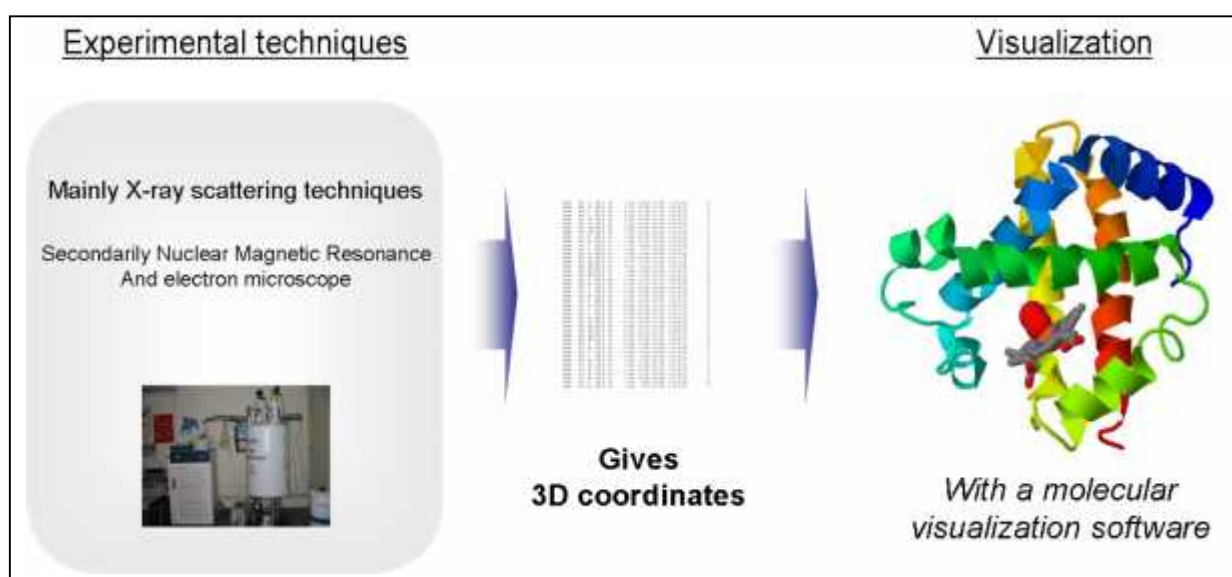
Figure 1: Way of obtaining a 3D model of a molecule.
And a representation that can be observed with a molecular visualization software.

Today, the MV represents a major challenge in biology given the importance of knowing the structure of molecules. Indeed, the structure of biological macromolecules dictates their functions, that's why the MV is used in many parts of biology as [Watson & al. 09] retail it. They are eg used by every researcher who wishes to produce an image of the molecule(s) he studies to illustrate his point in an article.

Martz, professor emeritus at the MIT, greatly encourages the use of MV software in education through his website [Matz, 10] that may be the biggest website for MV resources for teaching purpose. In France, analysis of the national curriculum of "sciences de la vie et de la terre" (SVT), the equivalent of biology and geology, indicates that MV is tucked into this curriculum with a recommended use of MV software for some practical work. In scientific 11th grade (16 years old), as early as the 1993-1994 school year, that is to say as soon as the MV software was available to the general public and, in scientific 12th grade (17 years old), from the year 2000 and, for 10th grade (15 years old), in 2010. Furthermore, these MV software figure in the test to graduate from high school through the evaluation of experimental capacity in SVT, being present in approximately 10 % of the subjects offered.

The work presented here is part of a PhD interested by the transposition of a scientific tool, the MV software, into the educational world.

RATIONALE

As Yarden and Yarden (2009) show it with the use of a PCR animation as a visualization tool, the animated tool provides "a significant advantage to the students who used it over those who used still images". So animations can facilitate the comprehension of molecular processes.

Ferk, Vrtacnik, Blejec and Grill (2003) show on students from 13 to 25 that, on one hand, they have a better understanding of molecular models with representations on computer software with a MV software than with a 2D representation with a photograph or a schematic representation of molecular model. On the other hand, the correct perception of the 3D structure of the molecule is crucial for all subsequent mental operations related to molecular structures.

In the same vein, Berry and Baker (2010) show that "it is often extremely difficult to impart an understanding of complex three-dimensional relationships when using two-dimensional projection screens" and therefore molecular visualization software make "it possible to bring spatial relationships to life with three-dimensional images".

These studies thus show that MV software can be beneficial to the teaching of molecular concepts; therefore it is relevant to observe how the software is used in high school during SVT courses.

METHODS

It is difficult to get information on the use of software in the educational system in France. Indeed, there are no organisms or reports that gather information on this topic. That's why we had to use indirect approaches to get an idea of the result of the transposition of MV software in high schools in biology in France.

First we assumed that there would be some marks of this use on the French web. That's why we investigated it to find some hints that would show the use that can be done with MV software. We started to analyze the websites that are supposed to help teachers. These websites are the 35 academic sites (an academy is an administrative district of the French minister of national education, each one has is its own website with several resources for the teachers) and the site of the "National Institute for Educational Research" (INRP) through the section managed by the team of "Continuous Updating of Knowledge of Science Teachers" (ACCES) [ACCES 10]. And after, we used the search engine *Google* to find other websites that could give us some more information.

Second we analyzed textbooks of five different publishers (Bordas, Hatier, Nathan, Magnard and Hachette) from 1992 to 2010. Indeed, textbooks are very often used by French teachers to give their lessons.

Finally, we conducted interviews with six French high school (grade 10, 11 and 12 – age 15 to 18) SVT teachers known to be expert in the use of MV software. The questions asked aimed at knowing which molecular visualization software they used and why. How they discovered the software. The activities they have done with the software. The problems they face when using the software. And the possible improvement they could feel when using the software.

RESULTS

Analysis of the francophone web

The analysis of the francophone web showed that beside the academic sites and the site of the "National Institute for Educational Research" (INRP), information about MV software for teaching is not or barely not on other French websites.

On academic sites, the most often emphasized MV software is *RasTop* that was created in 1996 from *RasMol* in order to be adapted to the educational world. It is possible to find, on some academic website, activities using MV software intended to be made during practical work to introduce molecular concepts (like the structure of DNA). But they almost all refer to the section ACCES of the website of the INRP.

On the ACCES section, there are many information about the *RasTop* software: a fairly complete description of the software, molecules to download and examples of possible activities with this software. It also contains information on *RasMol* but far less significant.

We can also notice "Library of Molecules" website [Librairie de Molécules 10], a cooperative site, in which 11 academies participate, which provides molecular models selected by teachers for a classroom use. Nevertheless, website activity so far remains low.

There is thus, on the French web, a key role played by the ACCES section. With a focus on one software, *RasTop*, a pool of molecules available which has slightly varied from the one proposed by ACCES in the early 2000s and a small number of activities that also have slightly varied from the early 2000s. There is only a few opening on the English websites like the site of the *Protein Data Bank* (PDB) website which is the single worldwide repository of information about the 3D structures of large biological molecules. These results were reinforced by an analysis of user queries on the *Google* search engine and user requests to access to the site of the INRP (Author and Blondel, 2011). Finally it is important to note that, nowhere on the French web, the origin of molecular models and how to obtain them is questioned.

Analysis of textbooks

The textbook analyses showed that the images of molecular models presented are not or barely not exploitable because of the lack of precise data (no caption, unspecified representation, no scale, etc.). Some textbooks also offer activities similar to those offered on the web francophone. Finally, in the same way as on the francophone web, neither the origin of molecular models nor its status is explained. So the textbooks are insufficient in themselves to address the MV.

There is also an evolution during time, in the latest textbooks there are a bit more topics related to molecular visualization software. And there is the emergence of technical sheets on *RasTop* in the most recent textbooks.

Analysis of the interviews with the teachers

The analysis of the interviews with the teachers showed that they use the *RasTop* software during practical work to realize activities such as those described on the francophone web. They say they spend little time on the explanation of molecular models. They indicate that these molecular models are not always very clear for the students who may sometimes feel like observing a molecule and not observing a model constructed by scientists.

Question: Do students clearly understand the conception of molecular model?

Teacher: I am not sure, I am not sure at all, for example sometimes they believe that they are watching a real molecule in real-time and not a model…

Teachers indicate they regret the lack of molecules and examples available to use MV software.

CONCLUSIONS AND IMPLICATIONS

All the results obtained with the different approaches converge to say that there has been fabrication of a scholar tool with a reduction phenomenon on one software (*RasTop*), mainly one website (the section ACCES of the website of the INRP), few molecules and some activities. In addition, these activities remain illustrative whereas one might have expected some of them to enhance an investigation posture. And it seems that since 2002, the school practices are stabilized and did not change a lot.

Furthermore, it is important to note that the origin and status of molecular models are not or very little explained. Perhaps this leads to a misconception from the students about the molecular models as indicated in the speech of teachers. As Linn (2003) suggests it, perhaps visualizations confuse rather than inform learners.

PERSPECTIVES

It could be possible to study the "social practical of references" to propose some new activity that could renew the use of these software in classes. And thus design new activities with the collaboration of teachers.

We might also consider studying how molecular visualization is used in education in other countries, for example in the US.

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COHERENCE OF AN ICT-USING TEACHING SEQUENCE: A CASE STUDY IN OPTICS AT LOWER SECONDARY SCHOOL

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Abstract: This communication reports a case study based on a discourse analysis in an ordinary classroom, at grade 8 in a lower-secondary school in France, during a teaching sequence in elementary Optics. It particularly focuses on a part of the last session, where the eye is presented as an optical system using a lens, the focal length of which is variable. For this part, the teacher is using a computer-based simulation. The teacher's discourse is analysed from a threefold point of view: the modelling processes; the conversions between several semiotic registers; the coherence between this session and previous activities in the teaching sequence. From all these points of views, the use of an ICT tool offers new learning opportunities to students, or strengthens learning opportunities already offered.

Keywords: ICT, Coherence, semiotic representations, modelling processes, affordance.

1. INTRODUCTION

ICT-based tools have reached a high level of use in science teaching in developed countries; they have multiple uses (among different typologies, see for example Pinto and col., 2010). This use can be seen and studied more specifically, for instance when an ICT-based device is chosen by the teacher to fulfil a specified task, at a given moment of a teaching sequence. As far as students' learning is taken into consideration, the long-scale effects that is, the coherence of the ICT use regarding the other parts of the teaching sequence, must be analysed as well: what is the role of an ICT device in a teaching sequence? Is it used to introduce new notions or to reinforce concepts that have already been studied?

The theoretical tools that we shall use in this case study take into account the multimodal dimension in science teaching and divide among three elements: the modelling processes, the semiotic registers and the affordances or learning opportunities.

2. THEORETICAL FRAMEWORK

2.1. Modelling processes

Models and modelling are an essential dimension in science teaching. Tiberghien (1994) distinguishes between two worlds in teaching/learning physics. She defines:
- the world of objects / events as knowledge elements that refer to the observable and material world,
- the world of models or theories, as qualitative or quantitative notions and procedures that correspond to the generalizable aspects of the studied situation.

From this epistemological point of view, physics teaching can be considered fundamentally as a matter of modelling processes, of establishing meaningful links between "the world of objects and events" and "the world of theories and models".

Very often, ICT-based tools represent models of empirical realities, and one of the tasks of the teacher is to make this status clear for the students. For instance, in our case, the software used in physics (Cabri-Géomètre[1]) obeys the rules of physics and its representations belong to the world of theories / models.

2.2. Semiotic registers (semiotic representations)

Science classroom discourse is a particular one. It is multimodal in principle (Lemke, 1998) and uses several semiotic registers. Duval (1995) defines the semiotic registers in the following way: "they are the productions made by the use of signs (utterances in natural language, algebraic formulas, graphs, geometrical figures…)".

When using ICT in science classroom, many modes of representation, many "semiotic register" are used in the classroom discourse; the dynamic graphical representations, which are the core of most ICT-based tools, must be articulated with natural language (words and gestures as well), or static graphical representations (drawings or schemas on the blackboard, for example), or mathematical symbolism.

Duval defines some semiotics registers in mathematics education. We take in the following semiotic registers very often used in teaching physics:

- The register of natural language: it is the primary tool used before and / or during the acquisition of scientific vocabulary. This register is flexible that is, used in the world of objects / events, the world of theories / models and to make a link between the two worlds.

- The register that contains drawings, diagrams, and graphs:

a- a drawing is an "exact representation of the shape of an object" (Davy & Doulin, 1991);

 b- a schema is a representation of a referent. It can be non-figurative and figurative. A figurative schema refers to something sensible, visual and perceived while a non-figurative schema designates a mental referent. (Estivales, 2003, page 56).

2.3. Affordance versus Learning opportunity

The psychologist James Gibson proposed the term "affordance", in his ecological theory of perception (Gibson, 1979). He noted that the affordance depends on interactions between the animal and its environment: "*affordances as what the environment offers the organism"*.

In the field of ICT-based science education, Webb (2005) expresses a definition for the notion of affordance inherited from Gibson: "*In an ICT-supported learning environment affordances are provided by interactions between the hardware, software, other resources, teachers and other students*" (Webb 2005, p.707).

We consider as meaningful to introduce a distinction between two phases of teacher's activity when implementing an ICT-based activity in the class, regarding the coherence of the teaching sequence and the effects on learning. This distinction is a consequence of our socio-cultural point of view on science learning, which gives a key role to social interactions in the construction of knowledge.

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[1] www.cabri.com

When a teacher plans to use an ICT-based tool in a teaching session, he or she first chooses the software (or special functionalities of the software), depending on the school equipment, on the starting point of the students, on the teaching aims, etc. The teacher also foresees the way he or she will play the scene. We keep the term "affordances" for this set of characteristics that are planned before the session begins.

During the activity itself in the class, the interactions can widely modify what has been planned. When we analyse the classroom discourse, we find evidences of unpredicted suggestions by students, or unforeseen procedures (right or wrong) they use, which deviates the knowledge flow in the classroom discourse and activity, and consequently which can activate or inhibit previously organized affordances. We call *learning opportunities* the affordances that have been effectively offered to students during the classroom interactions; students can catch or not these opportunities, this is another question asking for different methodologies.

2.4. Links between the theoretical tools

These four kinds of theoretical tools are relevant with our purpose to analyse the coherence between the moments when the teacher uses ICT-based activities, and other moments of the sequence. These two kinds of activities can be at different modelling levels, on one hand, and use different types of representations on the other hand. Moreover, the term of affordance, as defined by Webb in the cited sentence, is essentially an integrated one, insisting on the various facets that constitute an affordance.

3. RESEARCH QUESTION

Taking into account the previous theoretical elements, the questions in this study are: how does the use by the teacher of an ICT-based tool construct the coherence of a teaching sequence? How does the use by the teacher of an ICT-based tool offer new learning opportunities to students, in the flow of classroom discourse?

4. METHODOLOGY

We have filmed a male physics teacher at the lower secondary school in France, during a complete teaching sequence. This sequence consists in six activities, each session lasting one hour and a half. This sequence[2] is a research-based one, as it has been elaborated in a joint group involving a researcher and several teachers.

We have indexed our video data of the entire sequence in a table (script). We identify the sessions where the teacher used the software Cabri in the sequence: two times. We have chosen to present here the analysis of a single use of Cabri (the second one, May 25).

We particularly looked at the moments when the teacher used the software, and we transcribed these moments. In the discourse of the teacher we searched all the indicators relating to the activities earlier in the sequence.

We present below (table 1) the "script" of the sequence including moments where the teacher used the software.

Date of the	Number of the activity	Learning objective indicated at the beginning of each activity	Content of the activity

[2] See the current version at http://pegase.inrp.fr/theme.php?rubrique=1&id_theme=57

session			
2010_04_06	Activity 1	1. Recognize the different types of lenses.	1. The students work in pairs to find among four lenses, which of them can serve as a magnifying glass. The strategy consists in looking through the lenses.
	Activity 2	2. Understand the effects of a converging lens in terms of optics.	2. The teacher introduces the terms *diverging* and *converging* lenses.
2010_05_11	Cabri (addition)		*Modelling a converging/diverging beam of light after passing through a converging/diverging lens.*
	Activity 3	3. Show that the energy is concentrated at the focus of the converging lens for sources situated at the infinite.	3. The students carry out experiments using a thermometer, a converging lens, a screen and a lamp. Students place the lamp as a light source followed by a converging lens. They measure the temperature of the light spot formed on a screen as they move it from the lens.
2010_05_18	Activity 4	4. Show that some specified condition is necessary to obtain an image .	4. The students send the light of the lamp on a slide with the letter P. The light passes through a fixed converging lens. Students move the screen (backwards and forwards from the lens) to obtain an image.
	Activity 5	5. Understand the vision mechanism from the point of view of optics.	5. The students establish the correspondence between the terms mentioned in the drawing of the eye (figure 1) and the following words in the text: diaphragm, converging lens and screen.
2010_05-25	**Cabri (addition)**		*Correspondence between the elements of the eye in a schema and a drawing.* *Convergence of the rays passing through a lens when they come from an object at a finite distance or an infinite one.* *Explanation of the accommodation phenomenon.*
	Activity 6	6. The corrective lenses for the eye defects.	6. Correction of eye defects.

Table 1: Script of the sequence titled "lens" (grade 8). The use of Cabri-files that has been analysed took place on May 25 (bold characters).

It was not planned to use Cabri-Géomètre in the sequence. That is why we have not completed the learning objective on the corresponding lines. The teacher was proposed to use Cabri files in this sequence by one of the authors, as they may facilitate the understanding of the modelling processes by the students.

5. ANALYSIS

We present the results of analysis according to each theoretical framework.

5.1. Analysis in terms of modelling processes

5.1.a. <u>Analysis of the files realised under Cabri Geomètre</u>

Cabri was used to model the convergence of light rays after passing through a converging lens. On this file, the teacher has the possibility to choose and modify the location of the object (finite distance, infinite distance) from the lens.
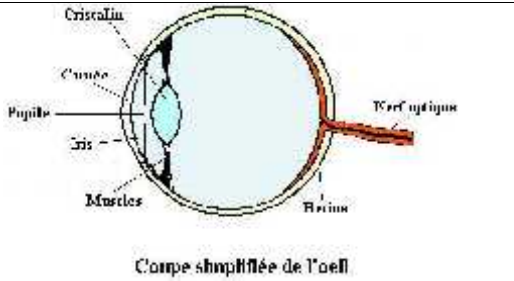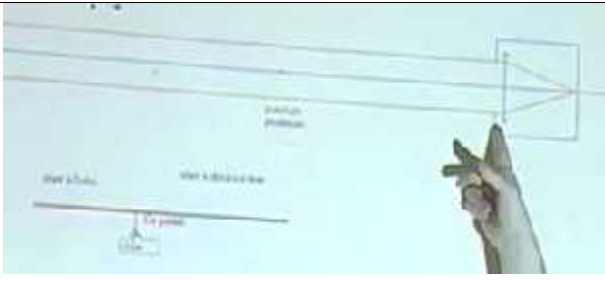
These Cabri files obey to the laws of Optics, and the representation obtained by Cabri refer to the world of theories / models.

Nevertheless there is a difference between the kind of representation adopted by the Cabri-files and the conventional representational rules of Optics: in Cabri-files rays are represented by lines without arrows, when optical rays carry arrows to indicate the direction of light propagation.

5.1.b. <u>Teacher's discourse analysis during the session</u>

The teacher's discourse allows us hypothesising that the teacher aimed at making a link between the two worlds. We base this interpretation on the observed identification of some elements of the world of objects and events (the crystalline lens, the pupil, the retina, all specified by the "drawing", figure 1) to corresponding elements of the world of theories and models: the lens, the opening in the square, the screen on the bottom of the square (figure 2).

In his discourse, the teacher tried to explain a phenomenon of everyday life (the accommodation) through a physical model. He suggested the situation belonging to the world of objects / events for students ("*Probably you noticed it when you are reading your textbook or a book, and you look at suddenly something far from you*") and then produced his explanation.

Figure 1: static representation of an eye.	Figure 2: dynamic representation of an eye, from a physics point of view; representation obtained by Cabri software; case of an object at an infinite distance from the eye.

5.2. Analysis in terms of semiotic registers

The teacher made explicit for students the difference between two semiotic registers: the graphic representation and the drawing (saying for example: *you see here is a schema, it is a schematic representation, not a drawing like what we saw last week*). Nevertheless this distinction is limited because these two kinds of representation were not present simultaneously.

Through his gestures when projecting the Cabri figure, the teacher has provided links between two semiotic registers: the schematic register and the register of natural language. In fact, the teacher pointed with his finger relevant elements on the representation; for the converging lens for example he said: "*light rays as they pass through the lens as they are all converging lens ....*" (figures 2 and 3).

Figure 3: dynamic representation of an eye, from a physics point of view (representation obtained by Cabri software; case of an object at a finite distance from the eye).

5.3. Analysis in terms of learning opportunity

Using Cabri-géomètre, the teacher introduced a temporality to explain the convergence of a light beam after passing through a converging lens. The convergence of light may appear to be stationary (stable) when students carried out an experiment with a light and a converging lens. The use of Cabri by the teacher allows students observing the phenomenon in two phases: the light rays before crossing the lens (first phase) and the light rays after passing through the lens (second phase).

The use of a Cabri file offers to students the opportunity to visualise, for the first time, the modelling of the image obtained by a convergent lens in the case of an object at a finite distance from the lens (figure 3). The teacher gave here a new learning opportunity to students, characterised by the fact that the image is formed on the retina of the eye, whatever can be the place of the object relatively to the lens.

5.4. Analysis in terms of coherence

At many occasions during these five minutes, the teacher refered to the previous activities performed the week before by students ("*you remember*"): he recalled the experiment showing that the image through a converging lens is located in a special place behind the lens (fourth activity); but he also indicated that the situation is different for the image formation on the retina (the screen does not move), and that is his way to introduce the changes in the focal length of the crystalline, the accommodation phenomenon. Moreover he made the parallelism between the fifth activity (the schema of the eye) and the modelling of an eye in the Cabri-environment.

6. CONCLUSION

In this episode, we can observe that the meaningful articulation between the semiotic registers, the modelling levels, the activities of the sequence, allowed to this experimented teacher offering new learning opportunities to students (such as the link between their everyday life experience and the accommodation phenomenon), and strengthening the learning opportunities which had been offered in the previous sessions (like the fact that the optical image is formed in a located area behind the lens).

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SCIENCE TEACHERS' INITIAL MOTIVATION FOR DISTANCE EDUCATION

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Abstract: The science teachers play an important role in the quality of science education, and in the reforms' implementation, consequently to expand programs on teacher's continuing education is essential. As from 1996, the Brazilian Law of Guidelines and Basis of Education regulated distance education (DE), and public universities could then offer distance continuing education (DCE), broadening their role in Education. This research aims to expand understanding on factors attracting science teachers to DCE. Data were collected through interviews and questionnaires (Likert scale) with 75 participants, mainly from elementary school (80%), who took a DCE course in 2008. The results were analyzed quantitatively and qualitatively and showed a heterogeneous profile with science teachers from both sexes, wide age range, and with different experiences in distance education. The initial triggering reasons to take a DCE ranged from personal, professional, and convenience. Despite some balance among all the triggering reasons, professional ones had more influence. The DCE theme, its content relevance, and flexible schedules, were also important considerations among all others identified. These results provide public universities some elements to attract science teachers to DCE programs and to support optimal execution, contributing to the improvement of science education.

Keywords: Motivation. Distance continuing education. Science teachers.

INTRODUCTION

Teacher plays a central role in the reforms implementation (Adams & Tillotson, 1995), as well as in the quality of science education, therefore expanding programs on teachers' continuing education is crucial to improve science education (Cunha and Krasilchik, 2000).

In Brazil, several reasons make the importance of science continuing education even more acute, such as deficiencies in pre-service education (Carvalho and Gil-Perez, 2000), inadequate legislation (Garcia, Bizzo and Malacarne, 2009), and the precarious conditions of teaching (Franch, 1995).

As from 1996, the Brazilian Law of Guidelines and Basis of Education (LDBEN/96) have regulated distance education, enabling public universities (Article 80 and 87) to use innovative approaches for science continuing education.

To create attractive DCE programs for science teachers, building a deep understanding on reasons that triggers adults to enroll in such courses should be a matter of research. Rurato, Golveia and Golveia (2007b) had already proposed a transversal approach to understand the characteristics and students' motivations, because these data can provide a set of elements that can be available to construct learning strategies for students to succeed.

Although an important subject of research, the science teachers' motivation to seek DCE programs is methodologically challenging to identify and measure in a systematic approach. Several authors have explored the reasons for adults to seek DCE. Fiuza (2002) suggested a slight predominance of personal over professional ones; O'Lawrence (2007) argues that

distance education' schedule flexibility enables an optimal life-work balance and was an important factor driving decisions to seek DCE; Moore and Kearsley (2007) demonstrated that improving skills for an optimal employment was the main factor. Our group has demonstrated that professional reasons play a central role in the teachers' initial motivation, specifically for science teachers (Garcia, Bizzo, Lemos, 2008).

What are the main reasons driving science teachers (or even preventing them) to seek DCE? Do personal reasons play a central role or seeking professional advancement in the career is more important? Understanding this will drive decision making to support optimal policies aiming to improve science education.

Most studies up to now do not separate reasons among sub-groups within the main study population. Do aspects such as gender, science background, age, and experience play an important role in the reasons to seek DCE?

This study aims to identify the reasons that attract science teachers to DCE. Also, this study aims to understand the impact of the teacher's profile (gender, age, education, teaching experience, and DE experience) on those reasons.

The results are relevant to universities that are interested in expanding their roles in relation to our society in general and to science education in particular. The data are also important for the construction of new distance education courses improving teacher education, and consequently the Science Teaching.

DISTANCE EDUCATION IN BRAZIL

Distance education can provide the necessary conditions for the expansion of continuing education programs. The last LDBEN/96 (Article 80 and 87) and some decrees (n. 5622, published in 20 December 2005, revoking the previous two (n. 2494 and n. 2561) regulated distance education, enabling public universities to expand their roles in relation to education and society.

The Higher Education Census of 2009 showed an advancement of distance education in Brazil. Of all enrolment held in 2009 14.1% were in this modality of teaching. There was a large increase in the number of graduates in graduate courses. In 2002 there were 133.000 graduates, and in 2009 they were already 241. 000 studying in distance education.

The Ministry of Education implemented a series of policies for the expansion of distance education. We emphasize, among others, the creation of the Department of Distance Education (SEED) and the System Open University of Brazil.

Motivation and teachers' profile

Palloff and Pratt (2003) suggest that the successful virtual student consist of working, mature people who are trying to better their opportunities, self-learners who can conduct their study schedule without having teacher to charge them, they know how to ask questions, exchange information and develop ideas.

On the other hand, Ferreira and Mendonça (2007) state, for example, that women consider the DE as a good alternative for education, because they have daily work and duties of home.

Understand science teacher profile who seeks the distance continuing education, their characteristics may help professors and tutors create new pedagogical activities. However,

this profile will be better understood if it is related to other characteristics like motivation for seeking distance continuing education.

Motivation is an inner process that triggers, maintains and directs behavior. It is a psychological state, a driving force by which humans act achieving their goals (CAMPOS, 1989).

The motivation topic has promoted investigations from researchers from different disciplines. Characterized as an internal component of a person, motivation is fundamental for understanding attitudes, behavior, learning, performance, and the participation in distance continuing education.

Because motivation is not a directly observable phenomenon, it is investigated by studying people behavior in order to identify and understand the reasons underlying their inclinations and actions. Murray (1986) states that although there are multiple visions and conceptions of motivation there is a consensus that is the reason, such as internal factor, which initiates, conducts, maintains, and integrates a person's behavior.

The reasons, according to Hersey and Blanchard (1986), are synonymous of desires, instincts, impulses, needs and interests of the person. Motivation is related to the intensity of these reasons. For Lima (2000) one reason is a construct that can not be observed, and is constructed by the person to explain why he or she has the need to act in this or that way to perform an action. Thus, both the strength of each reason and the standard of them have an impact on how the person understands and interacts with the world around him.

Adults have a variety of reasons to learn and to make choices about learning. In the United States, Moore and Kearsley (2007, p. 174-175), state that students have as initial reasons for enrolling in distance education courses the compliance with university credits, the search for new knowledge, personal investment, the attempt to improve the income and employability.

Fiuza (2002), in a study of motivational aspects related to distance education in a master's degree distance course, listed a set of motivating factors (reasons) that lead workers to seek the distance education. The author has grouped the frequency of student responses showing a slight predominance on the personal aspects over professional ones. In another study, over a distance course of specialization, Gomez (2000) showed that participants were motivated to pursue the distance course by professional, personal and practical reasons.

O'Lawrence (2007) in his article "An Overview of the Influence of Distance Learning on Adult Learners" reveals, on one hand, that adults participate in distance education programs to enhance their skills, by the pressure of having to earn a diploma and because the incentives they receive from their employers. On the other, the author identified other issues such as lack of time, transport issues, optimal life-work balance, and flexibility of the course.

In a study in 2008, studying science teachers in a distance continuing education our group found that professional reasons play a central role in the teachers' initial motivation (Garcia; Bizzo; Lemos, 2008). Although in this study we only grouped the reasons (the frequency of student responses) that motivate science teachers to seek distance education.

METHODS

This study aims to identify the reasons that attract science teachers to DCE. Also, this study aims to understand the impact of the teacher's profile (gender, age, education, teaching experience, and DE experience) on those reasons.

With this goal in mind, our group decided to select a DCE science course applied by a public university for free. After identifying the study population, a sample of the teachers was selected to be interviewed (N=12) and results from those interviews were used to prepare a questionnaire. After the initial validation of the questionnaire with a pilot study (performed with 11 other teachers from the same study population), all teachers (N=138) received the final version of the questionnaire. Data collected from the returned questionnaires was compared and contrasted to achieve the study goals previously described.

The questionnaire consisted of open-ended questions and one Likert scale. We collected data on the participant profile: gender; age; academic background, graduate degree (yes/no), teaching experience (in years), and distance education exposure (yes/no). As to initial motivation for choosing this type of DCE we used a Likert scale with 27 items.

The raw data from the returned questionnaires (75 out of 138 participants) was analyzed forming three main groups of latent variables called domains (personal reasons, professional reasons, and convenience reasons). The consistency of three latent variables was checked using Alpha of Cromback, showing levels higher than 60% (according to Pestana and Grangeiro, (2005) it is acceptable to social science one alpha > 0,6).

Data were analyzed using the Statistical Package for Social Sciences (SPSS 16.0 for Windows) and "R" (http://www.r-project.org). To compare the domains related to gender, graduate degree, previous exposure to DE, nonparametric tests (Mann-Whitney test) were used. To compare the teaching experience and the three main domains, the Kruskal-Wallis was used. The correlation between age and each of the domains' variables was analyzed using "p" Spearman. To determine which domain had the greatest impact on the science teachers' initial motivation, Friedman' test was used. For all comparisons, we adopted a significance level α = 0.05.

RESULTS AND DISCUSSION

The selected course was performed annually by Sao Paulo University. Data was collected from the 2008 class. The course theme was "Nutritional Education: the food label in the classroom of elementary science education". The objective was to update science teachers in nutrition. The course had 60 hours performed over two months, with 58 hours of distance education and two hours final test (in person). From the 138 questionnaires submitted, 75 answered questionnaires were returned.

Results from the answered questionnaires showed teachers from different regions: South, Southeast, Midwest and Northeast. They were mostly women (80%) with an average age of approximately 33 years. Fifty-eight percent majored in Biology with a graduate degree (52%). Nearly 54% (53.3%) worked in a state public school, 78,3% in elementary school, 55.9% had more than five years of teaching experience, and 52% did not have any experience in DE.

The science teachers' initial motivation (reasons) to participate on the course varied widely. The higher scoring items are described below (table 1).

Table 1 – Science teachers' initial motivation (reasons) – 2008

	Statement	Mean	SD
MI03	Interest on the course topic for my classes	3,84	,436
MI10	Improve my professional knowledge on the topic	3,71	,653
MI11	Use professionally the acquired knowledge on my students	3,50	1,113
MI21	Flexible schedules	3,35	1,020
MI15	The fact that the course could improve the quality of my classes	3,31	1,185
MI25	The possibility of reconcile work and continuing education	3,28	1,008

MI24	Opportunity at the time the course was open	3,27	1,031
MI23	Technology, tools available (to attend the course)	3,24	,867
MI06	Because the course was free	3,22	1,264
MI26	The possibility of reconciling family life and work	3,11	1,169
MI08	Interest in information to improve my personal nutrition	3,05	1,038
MI01	Interest in taking a distance course in Nutrition Education	3,03	1,273

Among the most mentioned items, three were in the personal domain (MI01, MI06 and MI08), four to the professional (MI03, MI10, MI11, MI15) and five to the convenience (MI21, MI23, MI24, MI25, MI26). These reasons were the most important and influenced science teacher's decision to seek a DCE.

In the analysis of the interface between domains and variables (sex, age, graduate degree, teaching experience, and previous exposure to distance education), it was noted that all three domains were important influencers of the decision making to take a DCE. However, when teachers had higher levels of education (graduate degree, p=0.014) or with longer teaching experience (p=0.013), the professional domain had a more impact. Other analyzes yielded no statistically significant differences.

The test applied to analyze the correlation between each of the three domains showed that the professional domain (Median=3,00) was the most relevant to the science teacher's decision making.

SOME IMPLICATIONS

Data described previously listed the reasons to attract adults to distance education (Fiuza, 2002; O'Lawrence, 2007; Moore and Kearsley, 2007). The results presented here further expand the understanding on the science teachers' initial motivation to take a DCE course. Furthermore, explore how the teacher profile (gender; age; academic background, graduate degree, teaching experience, and distance education exposure) impact on the motivation to take a DCE course.

Rurato, Golveia and Golveia (2007b), in a study on the characteristics of students in distance education and the motivating factors, proposed a transversal approach to know the characteristics and motivations of students. According to these authors, these data can provide a set of possible elements helping professors to construct learning strategies for students to be successful. However, our results suggest more than a simple cross-cutting approach to know the characteristics and motivations of science teachers. They point to the need to explore the science teachers' profile attracted to the DCE and connect it to the initial motivation.

The implications of those conclusions bring the need to ensure a deep understanding of several aspects of the DCE to design an optimal course. In those three domains is required a combination of the theme, current and relevant, the relevance of knowledge, current, contextualized with links to teacher personal and teacher professional life, and schedule flexibility enabling an optimal life-work balance

Also it is relevant to shape courses differently to specific subgroups of teachers according their initial motivations. Those science teachers with higher levels of education or with longer teaching experience, who were attracted by professional reasons, and the others, who were attracted by personal or convenience reasons, need to have their interests assisted in different pedagogic perspectives.

Finally, we stress that these results are important to universities. Public universities can expand their roles in relation to our society in general and to science education in particular.

They have enough information to attract science teachers to DCE programs and for the construction of new DCE courses improving teacher education, and consequently the science education.

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PRACTICES IN THE TEACHING OF SCIENCES IN SCHOOL INCLUSION OF A BLIND PUPIL WITH DELLEMAN SYNDROME

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Abstract: This research investigates the use of Assistive Technologies (AT) in the process of inclusion of a visually impaired pupil based on different actions involving the teaching of Sciences, the school community and the family. A qualitative research approach was used, and a case study framework was adopted. The field of study was a state school in the city of Boa Vista, Roraima, Brazil, which accepts people with special needs in regular groups of the elementary school years. The object was the teaching of Sciences. The subject was a blind student with Delleman Syndrome who has undergone 21 surgeries. The subject uses AT as resource to assist in school attendance, in the personal development process and in the construction of knowledge and learning since early education. Interviews on the object of study were also conducted with teachers of Sciences in ordinary groups with special pupils and teachers working in teaching rooms equipped with visual resources. This approach afforded to understand the reality being investigated.

Keywords: School Inclusion; Assistive Technologies; Pedagogical Practices for the Teaching of Sciences.

INTRODUCTION

In Brazil, the National Policy for Special Education in the Perspective of Inclusive Education established the right to education to all children with special educational needs. In this sense, one of the focal points of this policy is regular teaching practices in conjunction with specialized educational service, which has to be offered before or after the respective daily school shift. Programs to enrich curricula, language teaching and specific communication and signaling codes also have to be included, apart from Assistive Technologies (AT).

1. THE TEACHING OF SCIENCES IN THE SPECIAL EDUCATION CONTEXT

The need to promote and develop the teaching of Sciences lies in the fact that these variables afford the student to better follow the evolution of science as well as the transformations that take place in nature and in human history. In this context, apart from being informative, the teaching of Sciences may also endorse scientific reasoning.

With this objective in mind, the Ministry of Education (MEC) implemented the National Curriculum Parameters (PCN) and, in the context of Special Education, adopted a set of guidelines titled "Curriculum Adaptations of National Curriculum Parameters in the Teaching of Pupils with Special Needs" (BRASIL, 1998).

The teaching of Sciences to visually impaired pupils demands from the teacher more than the development and application of activities focused on the content to be taught. Ironically, the persistence of a methodological and conceptual link observed between these teaching contents and visual didactic and pedagogic models adopted in scientific theories makes it more difficult for the teacher to bridge the didactic transposition as expected (CAMARGO *et al.*, 2006).

Another aspect that deserves to be stressed is the fact that Assistive Technologies may be used as interfaces in the learning process, which leads to more intense interaction and independence of the blind pupil in the classroom environment, promoting learning skills.

2. The pedagogical practice in Sciences: the data obtained

This study relied on the cooperation of eight teachers of an elementary school in the State of Roraima, Brazil. Based on the roles each teacher performed, they were identified as follows: two Sciences teachers (P1 and P2), one educational advisor (P3), the school's principal (P4), one classroom teacher (P5) and three visual resources teachers (P6, P7 and P8). The subject assessed in the present study was a 17-year-old 6th grade junior high pupil called R., who has oculocerebrocutaneous syndrome (OCCS), also called Delleman Syndrome. This disease is a multiple syndrome of congenital anomalies characterized by orbital cysts, brain malformation, congenital cleft upper lip and palate, neurosensory deafness and focal dermal hypoplasia. However, the subject who participated in this study did not present brain malformation (BRANDÃO, 2010).

The periods the teachers who took part in this research were working with blind pupils varied between 1 and 10 years, mean 4.25 years. Concerning specialized teacher training, five teachers declared having no specialized education in teaching blind pupils, three informed that they had taken a specialization course for teaching special pupils, and these same teachers said that had taken a further education course and/or participated in occasional training programs to meet the needs of blind pupils.

In terms of the knowledge of the Braille system, the two Sciences teachers said that they did not know the system and that only the teachers assigned to visual resources activities had specific training for that purpose. The same was observed concerning the teachers assigned to pedagogical tasks in the school.

When analyzing the pedagogical practices carried out by teachers and how ATs are used by R. in Sciences classes in terms of accessibility, inclusion, formation, as well as the knowledge and the perceptions the teachers have about these technologies and their notions concerning teaching and learning using ATs in the case of a disabled subject, we observed that:

• The views about teaching, learning and visual impairment vary considerably among the members of the study group, from a transmission-reception approach to a view based on the interaction between teacher and pupil.

- Considering the teaching process that resorts to ATs, only the visual resources teachers understand that the teaching process is not restricted to the classroom and the blackboard. For these teachers, "there is no single way to teach; everything depends on the pupil's needs" and "the creativity of individual teachers is very important".

- Considering the learning process, the teachers did not identify the difference between the use of ATs and the blackboard. The didactic strategies and/or tools they utilize in the classroom so as to facilitate the learning by a blind pupil in Sciences classes are the "blackboard", "speaking louder, nearer to the pupil so as to afford him to listen in better", "dictations of the activities for the pupil to copy". However, both stress the fact that the visual resources classroom is the site that has the technological and didactic resources that facilitate the learning by blind pupils.

- Three teachers answered directly that the technological and didactic resources that facilitate learning are located in the visual resources classroom. One of these teachers stresses the fact that these "are essential resources in the learning process", mentioning "the importance of the slate and of the stylus, since the blind pupil is unable to write without these instruments". Also, it was said that "the use of the Braille System is the first step for the inclusion of a blind pupil". Three teachers did not answer the questions about learning.

- The words of the Sciences teachers afforded to observe that they use the visual resources classroom as the only technological tool, since "it is the place where capacitated professionals are available to direct pupils in their extra-class or complementary classroom activities".

The techniques and strategies used by teachers of Sciences evaluated here are still based on expository classes. When planning the activities in a classroom with visually impaired pupils, it is the teacher's duty to offer the pupil the conditions and opportunities to explore his/her own intellectual skills, promoting a multi-sensory learning process (SILVA, 2006).

Concerning the pedagogical practices in the classroom that aim at the pupil/teacher and teacher/pupil interaction, teachers P1 and P2 underline the importance of classes based on traditional methodologies, as in the "blackboard", as well as of the sporadic group work and of Sciences lab classes. In R.'s own words, "In the Sciences lab she allowed me to grab things so as to better perceive them".

When commenting on the didactic strategies and/or resources used in the classroom to facilitate the learning of Sciences, P7 says, "The material is adapted as requested by the teacher and he would very properly say that that material was not good for him and that it needed adaptation".

The interviews with the teachers and the *in loco* observation carried out during the two years (2008 and 2009) R. was assessed prove that the subject did not feel difficulties to follow scientific reasoning and that he was very skilful in writing the classroom exercises in the Perkins device.

3.   Conclusion

The analysis of the data collected in the school investigated indicate the rather limited understanding teachers have of the inclusion of special educational needs, ATs,

and didactic resources for the blind and visually impaired. According to these teachers, considering R., learning and teaching using ATs (inclusion) takes place in the visual resource classroom.

The data collected and analyzed afford to observe the considerable limitations around the understanding of school inclusion, inclusion of pupils with special education needs, AT and didactic resources for the blind and those with visual impairment, from teachers P1, P2, P3 and P4, in the school where this research was conducted, in the state of Roraima, Brazil. In the opinion of these teachers, more specifically concerning the pupil R., teaching and learning using ATs (inclusion) take place in the visual resources classroom. However, P6 and P7, who are assigned to the classroom mentioned, understand that teaching and learning do not depend on the physical space as such, and that these activities are indeed influenced by the needs of a given pupil.

In this sense, the teaching of Sciences using these technologies, more specifically for R., and ATs, may add to supporting issues of didactic/pedagogical character more directly related to everyday school activities. Additionally, these technologies may enable the conditions to understand how the pupil with visual impairment interacts with reality, effectively developing his own learning processes.

Finally, the use of ATs in the teaching of Sciences not only facilitates accessibility and social inclusion of visually impaired subjects, but also promotes the teaching and learning of the subject, affording the pupil the tools to search for information he or she needs and (re)constructing his or her own knowledge.

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PRESCHOOL SCIENCE EDUCATION WITH THE USE OF ICT: A CASE STUDY

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Abstract: In recent years we have become increasingly aware of the need for people to understand the nature of science in order to make decisions posed by new developments in both science and technology. This case study is part of a wider research project concerning the use of Information and Communication Technologies (ICT) for teaching main natural science's concepts and mathematics in early year's classroom. The study was conducted during 2010-2011 school year and 270 pupils were participated. The integration of ICT into preschool education has become a high priority for everybody involved in the learning process. The Early Numeracy Test was given to pupils and semi-structured interviews with young children were conducted in 18 preschool classes in Crete. Pupils in the control group received only the traditional science instruction about natural sciences (solubility, recycling) and mathematical concepts (comparison, classification and general knowledge of numbers). Pupils in the experimental group received only the science instruction with the use of ICT for the same topics. Both the experimental and the control groups consisted of classes from the same participating schools. The incorporation of ICT in early year's classes in Greece should be considered as a means of an obligatory modernization of learning and teaching methods. The results of our research showed that teaching and learning through ICT as an innovative teaching method can be successful for understanding the concept of numbers and natural sciences phenomena at preschool level.

Keywords: Preschool Education, Mathematics, Solubility, Recycling, ICT.

INTRODUCTION

Science, apart from representations of the world, also involves ways of intervening in the world by putting things to work in the laboratory according to theories and models. Scientific literacy, the goal of science education, involves conceptual knowledge, problem-solving strategies, understanding the nature of science, and an appreciation of the interaction between science and society (Stohr-Hunt, 1996).

Science education at the preschool level with the use of ICT (Information and Communication Technologies) that emphasizes active learning, may be expected to promote higher student motivation than what occurs in traditional classroom settings with teacher oriented learning. Numbers and natural phenomena invoke the interest of children from a very young age (Geary, 1994; Bryant 1997; Chen, 2009). Our research reveals ICT uses in Greek preschool education and explores this use of ICT for science education.

THEORETICAL FRAMEWORK

During the last 10 to 20 years European countries have had problems engaging students in science (Osborne & Dillon, 2008). Children construct their knowledge of the world on the basis of two information sources-observations of the world and explanations given by other people (Vosniadou, 2002; Kikas, 2003).

Scientific concepts may be hard to grasp even by adults; however, this does not mean that children cannot think abstractly about scientific concepts. On the contrary, literature shows that children are able to think about even complex concepts (Zimmerman, 2000). Learning theories now accept the importance of learning processes at this age and, moreover, research studies have provided strong evidence that appropriate teaching interventions can help pre-school children accept basic scientific ideas concerning common phenomena of the natural world (Ravanis, 1994).

Pupils' responses to events involving changes of state and dissolving have been studied in a variety of contexts over the past two decades. For Slone and Bokhurst (1992) the child is be able to consider both variables, the sugar and water, simultaneously (dependent on preservation), must understand direct and inverse relations (dependent on liquefaction or atomism), and must have the ability to assign numbers to the amounts of sugar and water and to compare the ratios. According to Prieto, Blanco and Rodriquez (1989), ideas held by 11 to 14-year-old Spanish students about solutions and the process of dissolution attach a good deal of importance to the mechanical actions and manipulations involved in dissolving the substances (e.g., stirring, shaking, heating, etc.). Lee et al. (1993) have reported about 50% of a sample of 11 year olds demonstrating an understanding of particle explanations for states, change of state, expansion and dissolving. For Papageorgiou and Johnson (2005) particle ideas helped with the development of 10/11 years old pupils' understanding of phenomena of changes of state and mixing.

In addition environmental education is recognized as an educational process that significantly promotes all aspects of an overall and balanced personal development of young children, in the psychological, emotional, cognitive, social and psychomotor sectors (Flogaitis, Daskolia & Liarakou, 2005). However, although the significance of environmental education in early childhood education has been recognized early on internationally (Tilbury, 1994) and efforts have been made for its inclusion in kindergarten schools, research in the field remains largely limited. Despite the fact that environmental education's general conceptual and methodological framework is widely accepted by the Greek educational community, the matter of its interpretation by national educational policy-makers and the approaches they promote for the application of environmental education at each educational level remains open (Flogaitis, et al., 2005).

The adequate preparation of teachers at all school levels in environmental education is considered, even today, to be lacking. The main emphasis has been primarily placed on the in-service training of teachers with the thought that most practitioners have not received any relevant pre-service training in environmental education (Flogaitis, et al, 2005).

A vast number of studies relate the appropriate use of computers with the ability of students to understand more efficiently the different mathematical notions (Dunham & Dick, 1994; Groves, 1994). Thus, it becomes obvious that kindergarten emerges as a very attractive environment of investigating the computer use in mathematics education. Indeed, various research results show a positive interrelation between the use of computer and the development of mathematical thinking in kindergarten (Clements, 2002; Clements & Sarama, 2004).

We consider it necessary to think of planning various activities related to science and technology, so that preschoolers would broaden their field of experiences and construct

certain primary representations, which would later on form the background to build up scientific concepts (Solomonidou & Kakana, 2000). Science education at preschool level with the use of ICT that emphasize active learning, may be expected to promote higher students motivation than occurs in traditional classroom settings with teacher-directed learning.

ICT use has been applied experimentally at the preschool level on a wide scope of skills and knowledge acquisition. Results demonstrated a significant contribution of ICT use in the classroom as a learning tool (Clements & Nastasi, 1992; Clements & Sarama 2003; Vernadakis et al., 2005). It is well known that children learn faster in an interactively functioning learning environment. This is probably the most important advantage of ICT use in the teaching process against traditional teaching. Moreover, the use of computers as a teaching tool allows children to learn at their own individual pace (Zaranis & Oikonomidis, 2009). Upon achieving one level of knowledge they can proceed to the next, which is not the case in traditional teaching.

Generally speaking, in order to maximize the benefits of ICT use in education, all the educators should keep in their minds this question: 'Can we use technology to teach the same old stuff in the same way or can we capitalize on the benefits of technology by using integrated computer activities to increase achievement? (Clements & Sarama, 2002).

METHODOLOGY

Our research study uses Early Numeracy Test (ENT) (Schopman et al., 1996; Aunio et al., 2004) and audio-recorded semi-structured interviews about solubility and recycling to explore the use of ICT in preschool classroom for teaching basic mathematical and natural sciences concepts. The ENT is a task orientated test which attends to measure the level of early mathematical competence. The test has been developed for kindergarten and consisted of forty items. The ENT consisted of eight parts and the tasks were spread over these parts in group of five. The ENT was examined individually. The components of the ENT where our study focused were: concepts of comparison, classification and general knowledge of numbers.

The semi-structured interviews focused especially on: solubility and recycling. The following questions were examples of what we asked the students: Does lentils, beans, chickpeas, rice, sugar, salt, pepper, and, coffee dissolved in water? What do you think when you hear the word recycle? What is recycling? Recycled camera? Recycled food cans, plastic bottles, stones? What is it made with the scissors, books, and bottles? Which buckets dump the plastic bottles, newspaper, and metal teapot? Recycled food? Draw a trashcan and a material that we throw into it when you do not need it anymore.

The study was conducted during 2010-2011 school year and 270 pupils were participated. The Early Numeracy Test and audio-recorded semi-structured interviews were conducted one-to-one in private and were given to children, aged from 4 to 6 years randomly selected, in 18 preschool classes in Crete (Greece). It took about half an hour for each interview or test and they were given to the children as a pre-test and post-test before and after the teaching intervention. There were two groups in the study, one control and one experimental. In the control group there was not a computer available for pupils' use, while in the experimental there was one. The research study was conducted from November 2010 to April 2011.

Pupils in the experimental group received only the science instruction with the use of ICT for the same natural sciences phenomena and mathematical concepts. Both the experimental and the control groups consisted of classes from the same participating schools.

The teaching process for both groups consisted of four weekly syllabus. The control group coordinated with traditional teaching. That included a story about the three little pigs that had three bags with sugar, beans and salt and passed through a great river. Another story was of recyclable materials, bottles, cans and paper that were neglected at the beach and they were very sad because they had been used and felt useless, until one day the newspaper brought the good news of recycling. Group and individual activities were given to children every day in order to understand what materials were recycled in the yellow bin, which the green and what in the blue bin. In addition they did experiments in which dissolved in water, various materials as sugar, salt, beans, chickpeas, lentils, coffee, etc. Moreover, there were quizzes given periodically and procedures were given at the conclusion of each number form one to ten.

The experimental group covered the same material at roughly the same time, but spent one class hour per week with the computer. The software was designed using the Flash CS3 professional environment and consisted of six distinctive counting activities for numbers from one to ten. Each one of them implicated pupils into different aspects of counting situations. More accurately, pupils were asked to reach solutions to problems, in which counting played an integral role. The computer activities were selected according to the kindergartens' curriculum and complements what children had been previously taught in class. The general environment of the software could be described as open ended, which allows pupils freedom of use and navigation, although there were some drill and practice features as well. Concerning the natural sciences phenomena the teaching intervention of experimental group used software which included stories and activities about solubility and recycling.

The role of the main teachers and student teachers were to be facilitators to help children solved any problems, but only when children really needed help. The data analysis from the tests was carried out using SPSS (ver.19.0).

RESULTS

The ENT and interviews were taken by 270 pupils. One hundred and thirty one of the pupils were male and one hundred and thirty nine were female. Data analysis was done by the SPSS statistical analysis program. Independent samples and paired samples t-test were carried out. The independent variable had two categories the experimental group (132 children) and the control group (138 children). The dependent variable was the total pupil's score from the semi-structured interviews about natural sciences phenomena (solubility and recycling) and mathematical concepts (comparison, classification and general knowledge of numbers).

The t-test for equality of means was not significant (t = -0.684, p = 0.495), indicating no significant differences initially, in numeracy and natural achievements between the experimental and control groups. Though the experimental group had a mean score (m=25.822) slightly higher than the control group (m=25.517), the mean difference was less than -0.300. The results of this pre-test are summarized below (Table 1):

Table 1: Independent Samples Test of pre-test

	t	df	mean difference	Sig. (2-tailed)
PRE-TEST	-0.684	206	-0.300	0.495

In order to determine if the performance of the experimental group was significant, a paired t-test was performed using the grades of this group for a comparison between pre-test and post-test of the scores. The mean grade for the pre-test of the study was 25.82 (SD= 4.39) compared to 35.35 (SD= 2.41) of the post-test. At α = .05 and df = 131, the critical value of

the t ratio was less than 0.001 (Table 2). Therefore, the post-test score was significantly different from the pre-test score in the experimental group.

Table 2: Paired Samples Test of pre and post tests in the experimental groups

	t	df	Mean	Sig. (2-tailed)
Pair 1 pre-test- post-test	-29.036	131	-9.530	0.000

Similarly, to determine if the performance of control group was significant, a paired t-test was performed using the grades of this group for a comparison between pre-test and post-test of the scores. The mean grade for the pre-test in the study was 25.52 (SD=2.51) compared to 34.65 (SD=3.23) for the post-test. At α = .05 and df=137, the critical value of the t ratio was less than 0.001 (Table 3). Therefore, the post-test score was significantly different from the pre-test score in the control group.

Table 3: Paired Samples Test of pre and post tests in the control groups

	t	df	Mean	Sig. (2-tailed)
Pair 1 pre-test- post-test ENT	-31.512	137	-9.130	0.000

Finally, an independent sample t-test was conducted. The t-test for equality of means was significant (t = -2.007, p = 0.046), indicating significant differences, in the scores between the experimental and control groups. The results of this post-test are summarized below (Table 4):

Table 4: Independent Samples Test of post-test

	t	df	mean difference	Sig. (2-tailed)
POST-TEST	-2.007	268	-0.700	0.046

Results of this study expand the research on the effects of appropriate programs embedded in a computerized environment for mathematics and natural science (Ravanis, 1994; Dunham & Dick, 1994; Groves, 1994; Solomonidou & Kakana, 2000; Clements, 2002; Clements & Sarama, 2004; Flogaitis et al., 2005).

CONCLUSIONS - DISCUSSION

Results of this study tend to confirm that ICT can be an effective method for teaching selected beginning scientific concepts and skills. Initially, there was no significant difference between the experimental and control group achievements. However, throughout the study, the experimental group had higher achievement than the control group. Despite that, both the experimental and control group had great achievements between the starting and the final level.

Using ICT appropriately with young children for science teaching is vital in early childhood settings. Pupils like use ICT mostly because it is something new compared to a traditional science lesson. Providing computers in each preschool classroom does not mean that the teacher will incorporate effectively ICT for science teaching. It is essential that early years teachers should be trained in the ability to apply ICT and to interact with the children during the learning process. Attending training programmes and keeping an open mind are the keys to a teacher's success.

This study is preliminary in its nature and is in progress. Other studies need to be designed, in order to replicate this treatment with a larger number of subjects and to attempt answering other questions that did not arise in this research.

The use of ICT in early childhood education is not a panacea and researchers ought to study more deeply the complex pedagogical issues involved in the uses of ICT. We argue that a change is necessary so as an innovative teaching method can be successful, not only concerning materials, but also concerning approaches and beliefs.

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KNOWLEDGE ORGANIZATION IN UNIVERSITY PHYSICS TEXTBOOKS

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Abstract: Textbooks are often the major source of knowledge in science education that provides teachers and students a conception of how scientific knowledge is organized. Therefore, it is of interest to recognize how knowledge is organized in the textbooks. In this study the knowledge organization in three introductory university physics textbooks are analyzed from the viewpoint of how concepts are structurally related. The examined subject is magnetostatics with specific topics of Biot-Savart law and Ampère's law. The method of analysis is based on the interpretative analysis and categorization, which recognizes the basic elements and basic links, which connect these elements. These basic elements and links form the skeletal structure of knowledge organization. Finally, the knowledge organization of textbooks are represented by using concept maps and classified qualitatively on the basis of their topological outlook, revealing the essential differences in their structures.

INTRODUCTION

The crucial role of textbooks on student's learning has been highlighted in many studies. For example, in National Educational Goals Panel (1998) of United States, there are some recommendations regarding the implementation of standards "Textbooks are where students meet the standards." It suggests that students and teachers should have instructional materials such as textbooks, which could help them to meet academic standards. Roseman et al (2010) analyzed the contents of four biology textbooks in order to examine their coherency. They specified the key ideas as well as other ideas within the textbooks and the alignments and connections among them. They reported that the judgments of their review team about the connections among key ideas were less consistent than the judgements about connections among key ideas and other ideas. Moreover, they noted that guidelines that were provided for making judgments about alignments were more explicit than guidelines about connections. In this research, it has been attempted to construct an explicit guideline for basic elements as well as guideline for connections (links) between basic elements.

Knowledge organization is an important component of understanding learning and teaching (Novak, 1982). diSessa (1993) argues that gaining an organized and integrated knowledge is a basis for cognitive processing (e.g. problem solving or complex reasoning). Teachers rely on textbooks in order to know how they should teach. Teachers would benefit considerably from textbooks if they are able to recognize and use such effective structures of knowledge organization in their own teaching (Ball & Cohen, 1996; Davis & Krajcik, 2005).Therefore, the in-depth understanding of the knowledge organization assists teachers to arrange their teaching materials. Similarly, understanding how knowledge organization possibly affects learning process is equally important. Knowledge organization is without doubt an important basic problem in all learning and teaching, but where do teachers and students actually get examples of those organized knowledge. For example, comparing knowledge organization of experts and novices has revealed that experts have an integrated and efficient knowledge organization with meaningfully related elements (e.g. principles and concepts) while students often have difficulties to organize their knowledge (e.g. students do not have sufficient interconnections between the pieces of their knowledge). Quite naturally, the study materials such as textbooks guide the development of knowledge organization of both teachers and

students. These notions motivate to find out how knowledge organization differs in different textbooks.

THE METHOD OF ANALYSIS

The purpose of this study is to find a way to present how knowledge in a textbook is connected and what kinds of structures knowledge organization these connections form. In order to make this explicit, the following research questions were established:

1. What are the characteristics of links (forming the knowledge organization) in different textbooks?

2. What kinds of knowledge organization exist in textbooks and how these organizations are different?

The first task is to develop a framework for analysing the units forming the knowledge organization. This includes recognising the basic elements like concepts and laws in the textbooks. Then the ways of connecting these basic elements (called here the links between the basic elements) are categorized. After developing the framework, the knowledge organization in the textbooks could be presented by using concept maps based on the categorized basic elements and links. In the recognition of the basic elements, the classification of elements suggested by Koponen and Pehkonen (2010) is utilized that posited that basic elements include concepts, entities, particular laws or law-like relations and principles.

After the basic elements were recognized, the connections between the basic elements in the textbooks were examined. In order to examine these connections (links), preliminary ideas of possible categorization were formed based on the role of experiments and modelling in the construction of knowledge (Koponen & Mäntylä, 2006). From the basis of earlier studies (Koponen & Mäntylä, 2006; and references therein), a category for experiments in connecting the basic elements was one reasonable possibility. However, the experiments were not detected in the studied textbooks in the cases of Biot-Savart law and Ampère's law. Harrison and Treagust (1998, 2000) investigated the textbooks stressing the use of models. They developed a typology of school science models to classify the textbooks' models. Their typology consists of mathematical and theoretical models, analogical models, models depicting multiple concepts such as maps, diagrams. Van Heuvelen (1991) classified physics knowledge into four main categories: words, pictorial representation, physical representation and math representation. In his classification, models somehow help students to construct representation of physical process, reason about the process, construct mathematical representations, and finally solve physics problems qualitatively.

Before forming the knowledge organization of textbooks, the classification of elements and links were judged in order to increase the validity of the analysis. For this purpose altogether six questionnaires (two topics and three textbooks) concerning the classification of basic elements and links in textbooks were designed. Four reviewers answered the questionnaires (i.e. judged the classifications made). These four reviewers are university lecturers with Ph.D. in physics, and they have taught first year physics courses. Hence, they are experts of the chosen topics of Biot-Savart law and Ampère's law, and they are familiar with the introductory university physics textbooks. Finally, the concept maps that depict the knowledge organization of textbooks were drawn. When drawing the overall concept map, these structure elements are put together: basic elements as nodes and the categorized connections as links between nodes. Here the application of concept maps differs from the traditional way: in a link of the map there is, instead a verb, a procedure that connects the basic elements to each other (compare with Koponen & Pehkonen, 2010). Then the features

of the knowledge organizations of textbooks made visible through the concept maps were qualitatively interpreted, analyzed, and compared. Calculating mean value and standard deviation of the items of questionnaires validated the interpretation and analysis of the basic elements and links forming the knowledge organization.

RESULTS

Recognized basic elements

Considering the topics of Biot-Savart and Ampere's law, BE are identified and presented in Table 1.

Table 1. Basic elements and their types identified in three studied textbooks.

	FLS	Type		HRW	Type		Knight	Type
1.	**Magnetic field**	**Concept**	*1.*	*Magnetic field*	*Concept*	*1.*	*Magnetic field*	*Concept*
2.	**Electric current**	**Entity**	*2.*	*Current- element*	*Entity*	*2.*	*Current- element*	*Entity*
3.	**Electric field**	**Concept**	*3.*	*Electric field*	*Concept*	*3.*	*Electric field*	*Concept*
4.	**Gauss's law**	**Law**	*4.*	*Gauss's law*	*Law*	*4.*	*Gauss's law*	*Law*
5.	***Biot-Savart law***	**Law**	*5.*	*Biot-Savart law*	*law*	*5.*	*Biot-Savart law*	*law*
6.	**Magnetic field of straight wire**	**Law-like relation**	*6.*	*Magnetic field due to a current in long straight wire*	*Law-like relation*	*6.*	*Magnetic field of a long straight wire*	*Law-like relation*
7.	**Magnetic field of a solenoid**	**Law-like relation**	*7.*	*Magnetic field of a solenoid*	*Law-like relation*	*7.*	*Magnetic field of a solenoid*	*Law-like relation*
8.	**Ampere's law**	**law**	*8.*	*Ampere's law*	*law*	*8.*	*Ampere's law*	*law*
9.	Vector potential	Law-like relation	*9.*	*Magnetic field of a coil*	*Law-like relation*	*9.*	*Magnetic field of current loop*	*Law-like relation*
10.	Stokes theorem	Law-like relation	*10.*	*Superposition*	*Principle*	*10.*	*Superposition*	*Principle*
11.	Maxwell equation	Law-like relation	*11.*	*Magnetic field inside a long straight wire*	*Law-like relation*	*11.*	*Magnetic field inside a current carrying wire*	*Law-like relation*
			12.	Amperian loop	Entity	12.	Coulomb's law	Law
			13.	Magnetic field due to current in a circular arc of wire	Law-like relation	13.	Magnetic field of current	Law-like relation
			14.	Magnetic field of brain activity	Law-like relation	14.	Magnetic field lines	Entity
			15.	Magnetic field of toroid	Law-like relation	15.	Charge	Entity
			16.	Magnetic field outside a long straight wire	Law-like relation			

* Common basic elements in three textbooks are indicated by Bold. Common basic elements in HRW and Knight are indicated by Italic.

Basic elements in all of the textbooks are identical. They have eight basic elements in common (from 1 to 8 in Table 1). The textbook of FLS has less basic elements than the other two textbooks; moreover this textbook includes some advance basic elements (e.g. Vector potential, Stokes theorem, Maxwell equation). The textbooks of HRW and Knight have eleven elements in common (from 1 to 11 in Table 1).

Categorization of links

The method of analysis and categorization of links needs consistently to specify the nature of links and to show how they connect the basic elements. In examining how the basic elements were connected, the links were categorized as follows:

1. Descriptive model (DM): A mathematical model that connects basic elements through mathematical relations or equations. In general, descriptive model links basic elements with mathematical format to new laws with mathematical expressions.

2. Explanatory model (EM): A mathematical model, which links basic elements through mathematical expressions. Usually the explanatory model connects the applications or implementations of laws (with mathematical format) to the closely related laws. In contrast

to descriptive model, which describes new laws, explanatory models explain the applications and implications of the defined laws.

3.   Visual model (VM): This model applies for visual perceptions. Visual model connects different basic elements through the diagrams, photos, and figures.

4.   Statement of fact (SF): Concerns declarative knowledge. This knowledge gives information about the facts such as observations, discoveries, and phenomena.

5.   Reasoning (R): A mode of presentation, which can be considered also as a model that gives reasons or arguments to justify the connections between basic elements. Reasoning might be inductive reasoning (reasons are based on the previous experiences or observations or laws) or deductive reasoning (reasons follow a set of premises).

6.   Reference to previous knowledge (RPK): A model, which refers to previous knowledge. This is often done in a form of analogy.
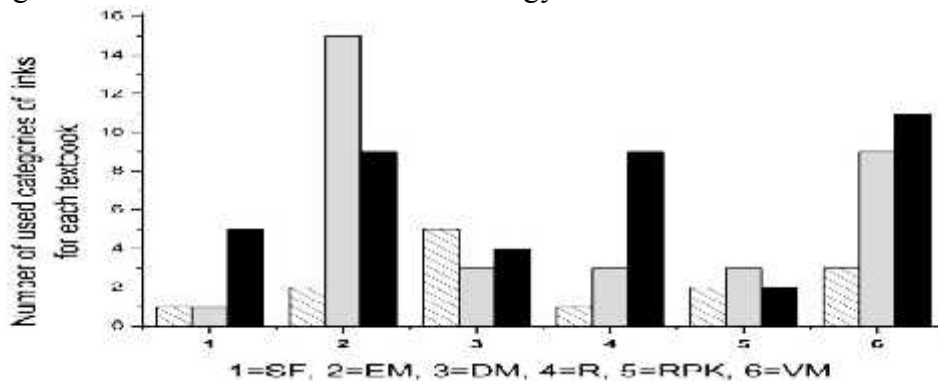

Fig 1. The number of categories of links. Used categories of links in FLS are shown by dashed bars, in HRW by gray bars and in Knight by black bars.

When comparing the total number of links, it can be seen that in FLS, there is only 14 links altogether and in Knight, there is 50 links. The HRW is between these two with the number of 34 links. Although, there is not a big difference in the number of basic elements between studied textbooks, but there is a big difference in the number of links between the textbooks (Table 1). In Fig 1, the number of links in respect to the types of links (1-6) in case of each textbook is presented in bars. It means that the tallest bar for each category (link) is the most applied link and the shortest bar is the least used link. It can be seen from the Fig 1 that in Knight (black bars) the different types of links are used in versatile ways. In FLS, the number of links (dashed bars) is low in comparison to other textbooks. In case of HRW, there is a clear emphasis on explanatory and visual models.

Representing knowledge organization of textbooks by concept maps

Since review team validated developed framework and created links, it is possible to make concept maps representing knowledge organization for each textbook. The recognized basic elements (presented in Table 1) are the concepts and connections between them are the categorized links (see last section). The concept maps are tried to construct in hierarchical fashion, where the hierarchical structure of a specific domain of knowledge depends on the context in which the knowledge is applied. The concept maps here include also cross-links, which connect different domains or segments of knowledge. The concept maps here differ in relation to the most prevalent way of constructing concept maps in one way: instead of propositions, the links are the categorized modelling procedures.
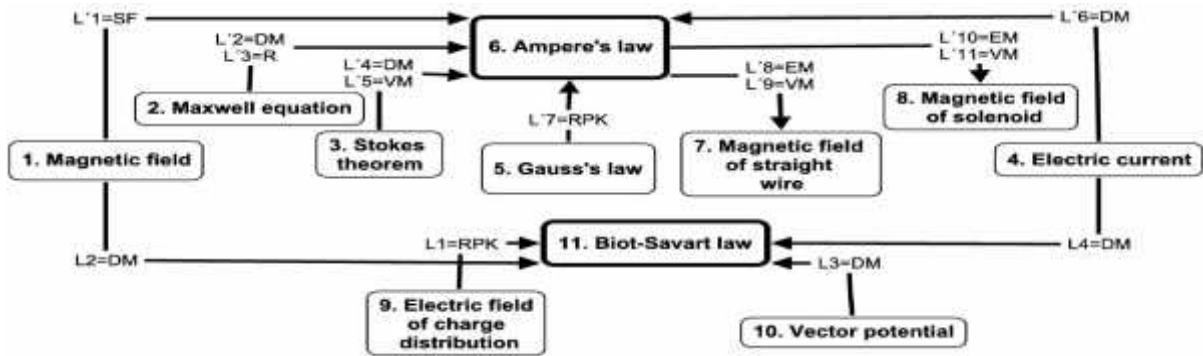
Fig 2. Concept map representing the knowledge organization of the textbook of FLS.

There are some incoming and outgoing links to Ampere's law (hierarchical structure) (e.g. Ampère's law connects to magnetic field via statement of fact, L´2=SF). There are only incoming links to Biot-Savart law (hierarchical structure), (e.g. electric field of charge distribution is utilized as an analogy (a type of RPK=L´1) to Biot-Savart law). Moreover, there are only two cross-links for the concept map of FLS. As Fig 2 shows, the knowledge organization of FLS has limited hierarchical levels, which means there are only few justifiable levels in the knowledge organization of FLS. The most dominant links in FLS are incoming links. Moreover, FLS includes few outgoing links and cross-links so its knowledge organization is not an interactive process. Ultimately, the knowledge organization of FLS can be interpreted as a simple structure that excludes interconnectedness but includes many disjointed concepts.
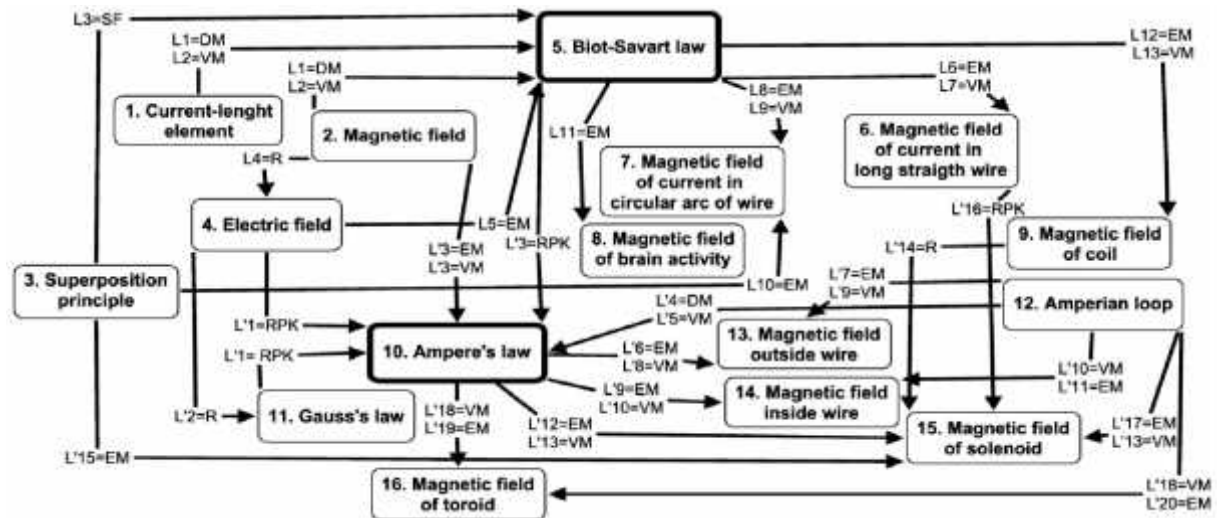

Fig 3. Concept map representing the knowledge organization of the textbook of HRW.

In contrast to FLS, Biot-Savart law is presented before Ampère's law in the textbook of HRW. There are only two dead end nodes in this concept map. There are incoming and outgoing links to Biot-Savart law as well as to Ampere's law. There are also some cross-links in this organization. As Fig 3 shows, knowledge organization of HRW includes many hierarchical levels. HRW describes high interactive process that includes some cross-links. Besides, the knowledge organization of HRW consists of many incoming and outgoing links. HRW includes only two disjointed concepts. Therefore, the knowledge organization of HRW is flexible and interconnected.
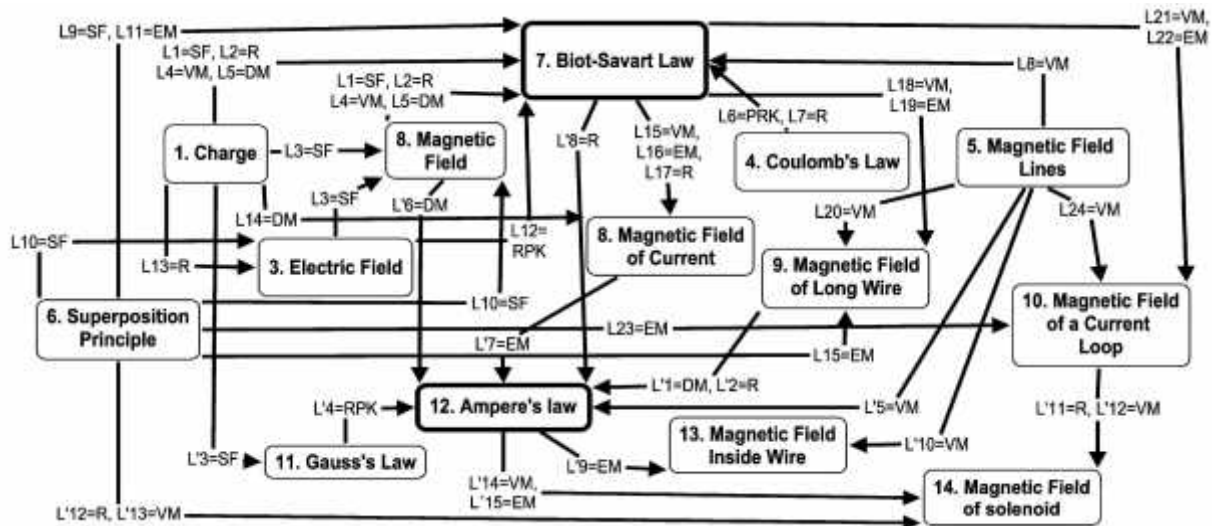
Fig 4. Concept map representing the knowledge organization of the textbook of Knight.

The organization of this concept map is somehow similar to HRW. In other words, there are some incoming and outgoing links to both core concepts. However, comparing HRW, there are more cross-links comparing to HRW. As Fig 4 shows, knowledge organization of Knight contains many hierarchical levels. Moreover, the knowledge organization of Knight is an interactive process that includes some cross-links. The knowledge organization of Knight includes many incoming as well as outgoing links. There is only one disjointed concept in the knowledge organization of Knight. Such an organization has flexible and interconnected structure. The knowledge organizations that are hierarchical and include interactive processes are more flexible and interconnected and therefore they are more beneficial for learning than simple structures.

CONCLUSION AND DISCUSSION

In this study, first the basic elements are specified. Second, a framework to categorize the links between the basic elements has been developed and validated by utilizing experts' ratings (resembles approach developed by Roseman et al., (2010)). Finally, the basic elements and links were presented by using concept maps and the knowledge organization of the textbooks was analyzed on the basis of the topological patterns in concept maps. On a basis of results introduced above, the research questions are answered as follows (the numbers refer to the research questions): 1) the links have different characteristics in the examined university physics textbooks. All textbooks used different types of modelling procedures to link the basic elements. However, the different textbooks used the links very differently. The FLS had only few links compared to other textbooks and the DM were the most utilized link type. In HRW, the link types of EM and VM were the most utilized ones. In Knight, there were substantially more links than in other textbooks and the different link types (especially VM, EM, and R) were utilized in versatile ways. 2) The knowledge organization of FLP has simple structure. As for knowledge organizations of HRW and Knight have flexible and interconnected structures. In conclusion, the knowledge organization of HRW and Knight are in many respects similar what comes to hierarchy and interactive process, and they are very different from the knowledge organization of FLS. Such fundamental differences in knowledge organization are bound to affect the views of the knowledge organization of physics that teachers and students obtain from the textbooks.

Here we have proposed a method to recognize basic elements and links between them within textbooks. We have shown that although basic elements for the same topics in different physics textbooks are similar, the textbooks apply different types, and number of links to

connect basic elements and eventually their knowledge organization is different. These differences of knowledge organization are revealed by using concept maps, which show the structural patterns of knowledge organization of textbooks and make the comparison between textbooks possible.

Recognizing the knowledge organization in the textbooks is an important subject in education, which affects learning and teaching. This method might actively engage students to think about the basic elements, links, and finally knowledge organization of the textbooks, and thus promote students' understanding of different topics in textbooks. Moreover, using this method may help students to organize their own knowledge and thus encourage them to understand whether their knowledge is well organized or not. Furthermore, other studies verify the impact of textbooks on teachers learning, as discussed earlier (see Ball & Cohen, 1996; Davis & Krajcik, 2005). The proposed method of this study, which recognizes basic elements and categorizes links, could be applied to analyze the quality of texts. Previous studies discussed earlier (e.g. Roseman et al., 2010) have emphasized the specification of the key ideas and the connections among them within the textbooks, but few of them carried out such investigation. In this study, in addition to recognition of the basic elements in textbooks, we developed a specific framework to clarify the nature of the links that connect the key ideas, basic elements of knowledge organization.

This research is continuing to explore the knowledge organization of university teachers by using the same kind of analysis method that is discussed in this study. The comparison of the knowledge organization of university teachers and university textbooks can reveal interesting aspects having influence in science education and teaching.

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STUDENTS' ACCEPTANCE OF A LEARNING MANAGEMENT SYSTEM FOR TEACHING SCIENCES IN SECONDARY EDUCATION

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Abstract: Learning does not take place only in the classroom. Nowadays, online teaching and learning has become a phenomenon and many believe that e-learning can be the next revolutionary change in education. E-learning is a way of learning supported by Information Communication Technologies (ICT) that makes it possible to deliver education and training to anyone, anytime and anywhere. Our research deals with the implementation of e-learning in the area of secondary education in Greece for teaching natural sciences. The Learning Management System (LMS) called Moodle (Modular Object Oriented Dynamic Learning Environment) was used for the creation of the virtual classroom. Asynchronous and synchronous communication was tried especially among the students, as well as between students and the instructor, aiming at cooperative learning. The main objectives of our study were to analyze the relationship of students' intention to use e-learning with selected constructs such as their attitude, perceived usefulness, perceived ease of use, self-efficacy of e-learning. The Technology Acceptance Model (TAM) is used in order to examine how students receive and how they use the Moodle platform. The positive attitude that is observed towards the model of blended learning and the Moodle platform did not appear to have high cross-correlation between use and intention of use. This fact was verified by the system's log files of students' participation in the attendance of internet courses and by the final acceptance questionnaire. The adoption of an appropriate pedagogical framework is needed in order to engage students and teachers in a LMS for teaching and learning natural sciences.

Keywords: E-learning, Sciences Education, Moodle, TAM, Secondary Education

BACKGROUND

Contemporary studies have focused largely on the examination of students' ideas/perceptions of concepts and phenomena within the field of natural sciences. In the following years, students have to develop a more active role in the educational process, and consequently the student must be the main person in the learning process. Contemporary instructional approaches expect students to be active producers of knowledge (Psycharis, 2011). Information and Communication Technologies (ICT) are considered to be largely applicable for natural sciences as they enable representation of phenomena, foster experimental study and enable the creation of models and problem solving applications (Duit, 1995, Psillos & Niedderer, 2002, Psycharis, 2011).

Offering distance education and using ICT for teaching natural sciences is neither a simple nor easy task. Quality guidelines for e-learning courses are needed (Kidney et al., 2007). Learning Management System (LMS) is a software platform for managing a coherent educational electronic system. In particular, through LMS the management of electronic classes and the educational material in general is made possible, such as developing classes

through the platform authoring tools, introducing predesigned classes, and modifying, enriching or deleting their content. Monitor data are available to platform administrators and the teachers of the classes. The development of distance learning systems along with technological advancements enables the creation of a new dynamic technology in e-learning. Users' registration can thus be automated and access to classes can be controlled. Users' actions can be monitored from the moment they enter the platform to the moment the exit the system. This pedagogical methodology has to be near to the constructivist educational model (Martin-Blas & Serrano-Fernandez, 2009).

Moodle (Modular Object Oriented Dynamic Learning Environment) is an electronic learning environment (Learning Management System, LMS) which created in the 1990s by Martin Dugiamas, specializing in Computer Assisted Education (CAE). The development of Moodle was based on social constructivism emphasizing the importance of culture and context in understanding what occurs in society and constructing knowledge based on this understanding (Park, 2009). The present research was based on the use of Moodle 1.9.5 in teaching natural sciences in secondary education.

There are theoretical models that attempt to explain the relationship between user attitudes, perceptions, beliefs, and eventual system use. These include the Theory of Reasoned Action (TRA), the Theory of Planned Behavior (TPB), and the Technology Acceptance Model (TAM). Among these, TAM, proposed by Davis (1986) seems to be the most widely used by researchers. It is a model which explains the adoption behavior of computer systems by the users and calculates the level of acceptance. Figure 1 depicts TAM's three phases (Davis, 1986).
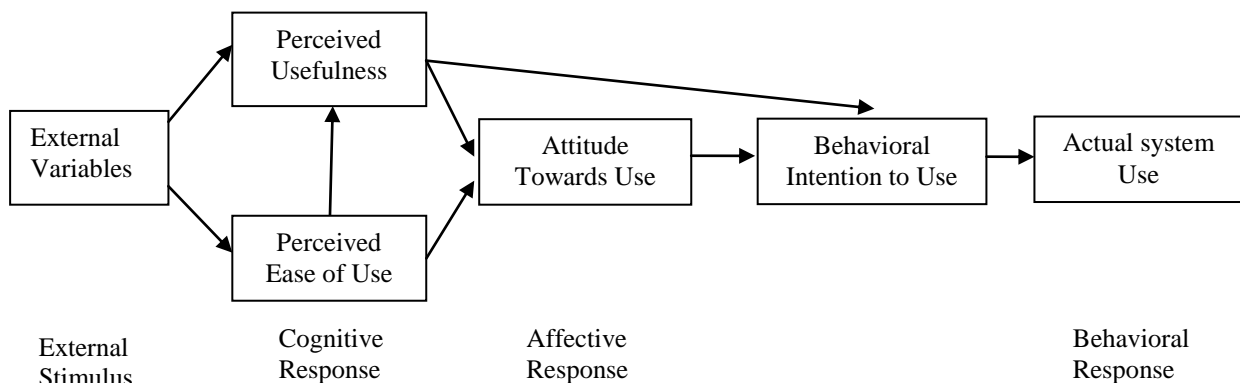

Figure 1: The three phases in TAM: Cognitive, Affective, Behavioral (Davis, 1986)

We used TAM for evaluating the Moodle platform in the framework of a course in natural sciences in secondary education in Greece. The TAM is an analytical simplification of how functionality and interface characteristics relate to adoption decisions. According to TAM, one's actual use of a technology system is influenced directly or indirectly by the user's behavioural intentions, attitude, perceived usefulness of the system, and perceived ease of the system (Davis, 1993). In TAM, technology acceptance and use is determined by behavioural intention (BI). BI in turn, is affected by Attitude Towards Use (ATT), as well as the direct and indirect effects of Perceived Ease of Use (PE) and Perceived Usefulness (PU). Both PE and PU jointly affect ATT, whilst PE has a direct impact on PU (Davis, 1986, Davis, 1993). TAM also proposes that external factors affect intention and actual use through mediated effects on perceived usefulness and perceived ease of use. Although TAM is considered as a well-recognized model in the field of information systems, little systematic research has been conducted in the LMS context for teaching natural sciences.

Selim (2003) argues that there is a need to investigate TAM with web-based learning. In his study, e-learning refers to pure, web-based, asynchronous learning. For Saadé, Nebebe and Tan (2007) university students' participation and involvement were important for successful e-learning systems. Therefore students' acceptance behavior should be assessed. They suggested that TAM is a solid theoretical model whose validity can extend to the e-learning context (Saadé et al., 2007).

FRAMEWORK AND PURPOSE

Aims of the research

One the main ambitions of our work was to get students acquainted with the model of blended learning as well as the use of Moodle environment. We implemented an on-line course as an extension of the face-to-face courses. We created, developed and applied an interactive learning environment for teaching natural sciences at secondary school level. Synchronous and a-synchronous communication was tried especially among the students as well as between students and the instructor aiming at cooperative learning. In the framework of the present research we explored the relation between perceived usability and actual ease of use of such a system, as well as the views towards a virtual learning environment in the model of blended learning.

Rationale

Students were faced up with time restrictions in school educational programs, the schools' infrastructure, the practical difficulties in computer and internet access and the established teacher-centered model. These limitations and the issues relating to the difficulty of applying an alternative pedagogical framework within the natural school space may be overcome by means of distance learning, through a particular LMS.

Our work examined the extent to which such an interactive platform can be used to eliminate such restrictions. We studied the levels of improvement in students' performance, their views towards the introduction of a LMS in natural sciences and also their levels of participation in interactive classes.

METHODS

This is a case study, and our sample consisted of 25 students (12 boys and 13 girls) of the Second Grade studying the course "General Physics", in a General Lyceum in Greece during the school year 2009-10. The learning level of the participants was characterized from good to excellent, based on the students' grades. One motivation for the students' participation was the awarding for participation in terms of grade, to a maximum percentage of 40% towards the final grade of the participants (60% from class performance and 40% from participation and performance in the LMS). The criterion for the school selection was the fact that it is a typical, district school. As far as the social status of the students is concerned, the majority of them came from agricultural or labour backgrounds (children of workmen or employers in private or public organizations), which corresponds to the vast majority of the economically active population in Greece.

In the first phase, the implementation and application of a scaled weekly plan of classes and activities was studied in the field of electric circuits. In this phase, the installation and organization of the Moodle platform was planned, the requirements with regard to hardware and software material were also determined and finally, the server for the webpage hosting the

educational and learning environment, including a computer system for synchronous and asynchronous distance learning, was selected.

In the second phase, the efficiency of educators' intervention was applied and evaluated, based on results from spreadsheets. In addition, the use and response to the educational and learning environment was evaluated by means of the system's log files and the respective response questionnaire. The manner in which the study was conducted was based on the quantitative approach. The spreadsheets and questionnaire on meta-learning experience consisted of closed questions, in true-false and yes-no format.

The final response questionnaire consisted of closed questions, under the Likert evaluation format. The creation of the questionnaire was based on a study of relevance to the research questionnaires, bibliography and online websites. Additionally, Moodle environment is included in COLLES (Constructivist On-Line Learning Environment Survey) questionnaire, the examination of which has been helpful in forming some of the questions in this particular questionnaire. The system's log files include numerical data and picturing the participation (for example, entries to the system per student). The process of the data is based on descriptive, statistical methodology (data presentation in tables and figures). For performance examination in spreadsheets, on the first level, there is the normality test Kolmogorov-Smirnov and the t-test evaluation on dependent samples (performance before and after teaching). In addition, in the criterion Wilcoxon highlighted, rank was used to make the comparison (between performance before and after), in cases where there is a variation in the normality test.

RESULTS

The final questionnaire is examined in terms of validity and reliability. In order to establish the conceptual construct validity of the questionnaire, the factual structure was examined, using the principal components analysis method (Tables 1 & 2).

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,571
Bartlett's Test of Sphericity	Approx. Chi-Square	262,168
	df	136
	Sig.	,000

Table 1: Sample Efficiency

Reliability Statistics

Cronbach's Alpha	N of Items
,552	17

Table 2: Scale Reliability

The evaluation of reliability was based on the internal effect with criteria method, the Cronbach "a" method, the item-item correlation testing and the corrected item-total correlations, in order to evaluate each question under this scale. Data processing was performed using the SPSS program, version 17.

The participation demonstrated that during the experimental application examined by investigation the log files were decreasing. The students' outside school preoccupations (such

as educational activities, sports, etc.) result in diminishing free time, which acted as a preventive factor to consistent participation. Students claimed they prefer to surf the internet without particular purpose, including social networking webpages such as facebook, rather than get involved in, or spend extra time on, the subject of physics on the internet. The performance grade (a percentage of 40% of total grade) as a means of motivation and award for participation did not appear to play a significant part. This is clearly due to the recently noted indifference of the students towards subjects of general education and their concentration on routine subjects. The examination system in Greece for entering Higher Education has, therefore, formed particular tendencies and results in similar views and behaviours on the part of the students, as far as ICT are concerned.

Factual correlations (Table 3) in the questionnaire, as answered by the students, show that the Perceived Usefulness (PU) of the System is loosely related to the positive view towards Environment Attitudes (EA) and Collaboration and Teaching Attitudes (CTA), whereas it is not related at all to the behavior towards use or Actual System Use (AS). In addition, Perceived Ease of Use (PE) is not related to positive views towards the system (EA) and its relation to Intention of Use (AS) is limited. Finally, there has been found no relation between positive views towards the system (EA) and Intention of Use (AS). The conclusions as set above have been taken into consideration and have been confirmed in the system's log files (course view) (Figure 2).

Component Correlation Matrix

Component	1 (PU)	2 (AS)	3 (CTA)	4 (PE)	5 (EA)
1 (PU)	1,000				
2 (AS)	-,062	1,000			
3 (CTA)	**-,269**	-,082	1,000		
4 (PE)	**,217**	**-,240**	-,189	1,000	
5 (EA)	**,328**	-,024	-,125	,005	1,000

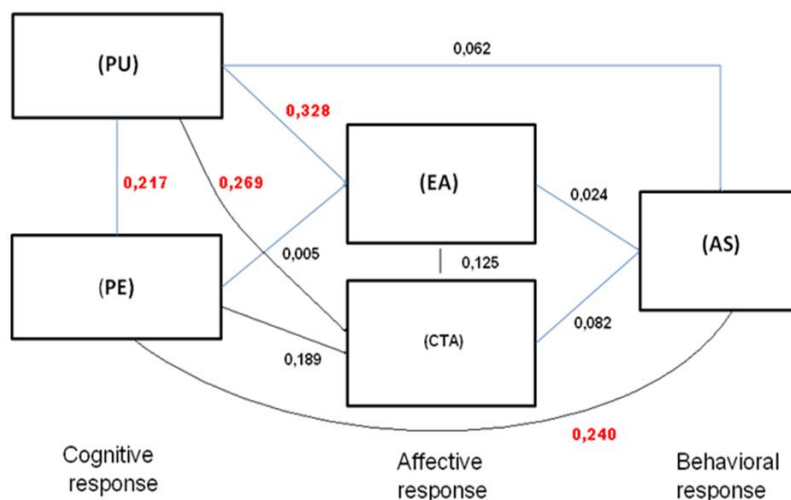**Table 3:** Matrix of factual correlations p<0,01

Figure 2: Factual correlation of response questionnaire

The students, in the majority being acquainted with PC use and the internet, can generally learn and use easily an interactive environment, such as Moodle. The collaboration among the students working in groups has had an effect on a third of the students' sample, who changed their decisions towards the correct answer as shown in the study of the answers to the questionnaires on metacognition experience.

CONCLUSIONS AND IMPLICATIONS

In general, students' concentration tends to be positively correlated to their intention to use Moodle for natural sciences. Thus, we should recognize these users as not only system users but also learners. Students can also perceive its usability in terms of the opportunities it can offer. However, the relation between; positive attitudes towards the system, its use and intention of use with perception of its usability, and ease of use is affected on a large scale by other factors. The need for free time, the general views towards school reality and learning in school, the way of life (role-models, values, behaviours) depicted in mass media, the mentality and practices of most educators (with limited exceptions), the lack of team-working experience, are all such conditions which require examination in order to establish how much they relate to the success or failure of e-learning.

The mode of teaching natural sciences and other subjects in schools is not oriented towards team-building learning activities and as a result the students' levels of collaboration are low, since they had never before participated in such an experience. As far as the development, application and function of an interactive environment is concerned, the educator who should attempt such a task shall be faced with difficulties technical and functional in nature from the start. They should be quite certain what is to be used, how to use it, where to publish it, who has the right or the obligation to access it and who controls it. As a consequence, issues such as hosting and platform installation to a larger or smaller extent, can be considered as an "adventurous" and demanding attempt. The knowledge required has not yet been available to Greek educators today by means of any educational programme (Kalogiannakis, 2010).

It should be possible for the use of interactive educational platforms to achieve the aims set, if the students are motivated towards the educational procedure and take full advantage of the possibilities that technology offers to direct and indirect effects within the educational environment. We shall not always consider anything new as something innovative and something to be adopted without control and consideration of other factors.

The choice of an appropriate pedagogical framework, the development, structuring and planning of learning through LMS require that educators who undertake such a project are familiar with ICT, well trained in pedagogical issues as well as in ICT, in order to support the achievement of teaching aims.

The findings of this research are valuable for the assessment of e-learning services in secondary education for teaching natural sciences which will pave the way for future improvement. Our findings should be interpreted within the limitations of a small-scale exploration study and more systematic research is needed. This type of research needs to be implemented in other e-learning circumstances or infrastructures. Future studies should also investigate the role of adding other variables such user experiences and user characteristics to those originally employed in the model. Apart from careful planning and determination of aims, it is vital that certain factors should be taken into account, including educational staff, material and procedures.

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A GAME IN THE CLASSROOM: WHAT DO STUDENTS LEARN?

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Abstract: This paper describes an empirical study relating to the use of a serious game in learning how to establish the chronology of geological events. This research involved 61 16-17 year-old students. The students' challenge consisted in reproducing different images of geological cuts with *Chronocoupe*, a game that simulates the consequences of geological events. The research is based on the *Theory of Didactical Situations* (Brousseau, 1986) and recent research in the field of the use of *serious games* for educational purposes (Egenfeldt-Nielsen, 2010). It aims at addressing the following questions: (a) Which elements should be taken into account in designing the game in order to induce the learner/gamer to engage in epistemic activities? (b) What do students learn when they succeed in the game?

The digital records of students' usage of the game allows one to draw behavioral and epistemic models of students (Wenger, 1987). Data sources of the study include the results of a test to assess students' capacity to determine the chronology of geological events as well.

The study shows that the design of the software must take into account that the students primarily use a trial and error strategy and that they are reluctant to shift to a strategy based on the analysis of the images to be reproduced. The study also shows that the students learn procedural knowledge, but they are not aware of the principles that they use when they are asked to establish the chronology of geological events.

Keywords: serious game, geology, science learning, epistemic modeling

1) BACKGROUND, FRAMEWORK AND PURPOSE

As gaming is one of the of the most popular occupations of youths, an increasing number of science teachers integrate serious games – *e.g.* digital games designed for educational purposes - into their teaching practices. However, few empirical studies have been carried out to explore the value of serious games for science education. It can certainly be said that digital games facilitate learning, but the evidence for saying any more than this is weak as most studies focus on the impact of game-based learning on students' motivation (Egenfeldt-Nielsen, 2010).

Our research aims at producing empirical evidence for the effectiveness of game-based learning for science education. Our work is grounded on the Piagetian hypothesis that states that learning is adaptive. Learning is considered to be an adaptive process (Piaget & Inhelder, 1966), the learner/player incorporates the game experience into an already existing framework (*assimilation*), while reframing his/her mental representations to fit new experiences (*accommodation*). Our work is also based on the *Theory of Didactical Situations* (TDS) (Balacheff, Cooper, & Sutherland, 1997). According to Brousseau, there is a strong link between problem solving (in a learning situation), and knowledge (as an instrument to mastering the situation). The learning process results from

interactions between the learner and a *didactical milieu* (*Ibid*.). The *didactical milieu* encompasses all the elements of the situation with which the learner deals during his/her activity. These elements are concrete, symbolic or human.

In our research, the TDS is employed to design the game (as a *didactical milieu*) and the setting of the learning session. The session is an *a-didactical situation* (*Ibid*.). This means that the objectives of the teacher are hidden, while the activity appears driven by exploration. As a result, the learner doesn't need to interpret the expectations of the teacher to succeed in the game (Ahuja, Mitra, Kumar, & Singh, 1995). The theory is also used to analyze the outcomes of the study by focusing on interactions between the learner/gamer and the game.

In this paper we address the following questions:

- Which elements should be taken into account for game design in order to permit the learner/gamer to be engaged in epistemic activities?
- What do students learn when they succeed in the game?

2) METHODS AND SAMPLES

Chronocoupe is a *serious game* designed for geology teaching. It is possible to download the software for free on the website of the author. The interface of the game (fig. 1) shows an image of a geological cut that can be generated by clicking the *event-buttons* (seven different geological events are implemented). Clicking an *event-button* modifies the image. For example, clicking the sedimentary button adds sedimentary layers and clicking the *fold-button* folds all the previous geological features. The game consists in reproducing the images of five geological cuts. The learner/gamer can compare his/her images with the images to be reproduced at any moment by clicking on the image. He/she is allowed to cancel only the last click, but a *restart button* allows him/her to restart the game. It is thus very difficult to reproduce an image by using a trial and error strategy.
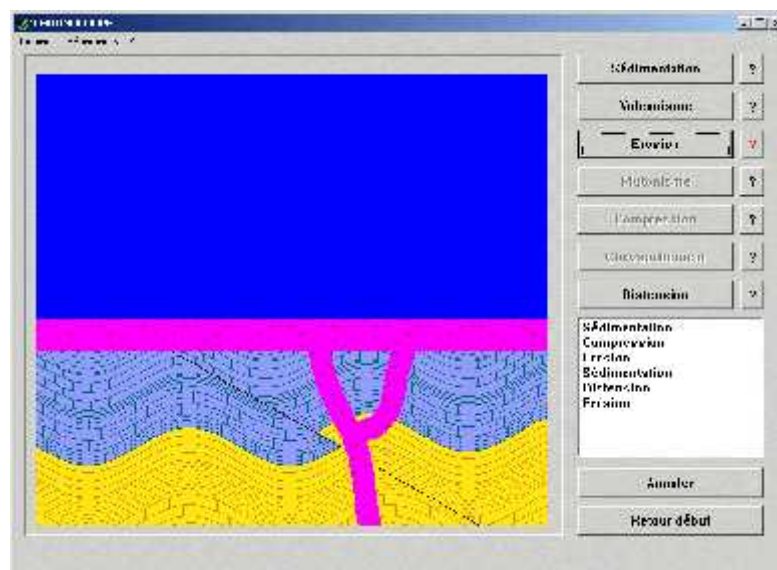

Fig. 1: *Chronocoupe*

The learner/gamer's success depends on his/her capacity to determine the geological event chronology of the different images displayed by the game. The chronology can be determined by applying the principles of stratigraphy. The *principle of superposition* states that, given normal conditions of deposition, new sediment layers deposit on the top of previous sediment layers. The *cross-cutting relationships principle* states that the geologic feature which cuts another is the younger of the two features. *Chronocoupe* is both a serious game and a simulation that simulates the forming of geological features and allows the player to explore the consequences of the simulation.

The experimentation was held with a sample composed of 61 students in the second year of upper secondary school in France (ISCED level 3A-16/17 years old). Each student used the computer individually. The students were asked to reproduce five images of geological cuts. The images were similar in terms of difficulty to reproduce. Different geological concepts, such as sedimentary process, magmatism and tectonics, were taught during previous teaching sessions.

The methodology of the research is based on the recording of the students' clicks (log files) to model each individual student's behavior. The log files are used to draw a chronogram for each student. This was done with a Microsoft Excel file designed by the author. A chronogram is a time line with colored bars that indicate the different clicks during the experimentation (fig. 2). Three indicators are used to compose a behavioral and epistemological model (Wenger, 1987) of the learner/gamer:

(a) The time devoted to reproduce an image indicates students' capacity to determine the chronology of geological events and to apply the principles of stratigraphy;

(b) The time devoted to the observation of the image to be reproduced is an indicator of the students' strategies. A short time indicates that the student doesn't base his/her chronology on a precise observation of the image, adopting a trial and error strategy instead.

(c) A high number of clicks of the restart button also indicates a trial and error strategy.
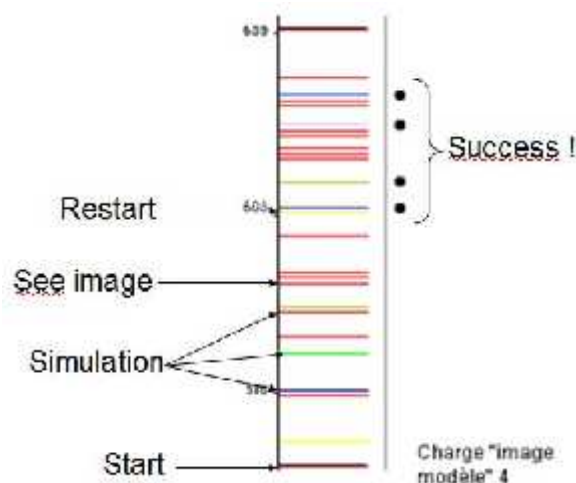

Fig. 2: Extract of a chronogram

At the end of the activity, the students were asked to take a test that consisted in determining the geological event chronology of an outcrop's image and to answer a short

questionnaire. Due to difficulties during data gathering, only half of the students answered the questionnaire, but the log files of 42 students were recorded and analyzed.

3) RESULTS

a. Students' capacity to reproduce the images

The average time devoted to reproduce the images (fig. 3) decreases over the course of the experimentation from a maximum of 4 minutes 12 seconds for the second image to 1 minute 36 seconds. Furthermore, inter-personal variability decreases. This result can be interpreted as the development of the capacity of the students to reproduce the *images* and the homogenization of this capacity for the whole sample of our study.
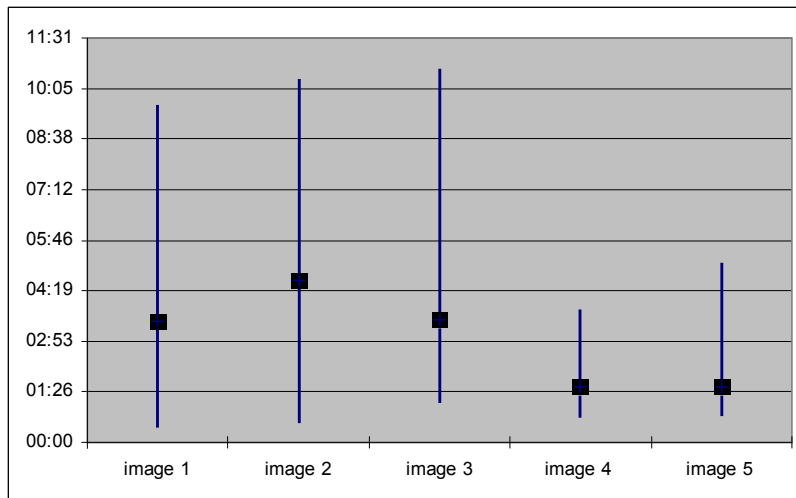

Fig. 3: Average time for the different images

b. Students' strategy shift

Regarding the strategies adopted by students, the comparison of two case studies, the students Elodie and Marie, illustrates two types of behavior. Marie completed the challenge in more than 17 minutes. She failed at reproducing two images. The chronogram shows that she observed the images to be reproduced very often, but during a very short time, usually by a 2 or 3 second glimpse, with 6 seconds as a maximum during the whole session. She very frequently used the *restart button*. All these observations constitute evidence that Marie's strategy consisted of a trial and error strategy, mostly based on chance. This was confirmed by her answers to the questionnaire. The short time devoted to the observation of the image to reproduce indicates that she was not engaged in a precise identification of the clues in the picture that can be used to determine the chronology. In Elodie's case, the session ended in approximately 11 minutes and she succeeded in reproducing all the images. During the first part of the session, Elodie's chronogram is similar to Marie's chronogram: frequent clicks on the *restart button* and short glimpses of the images to be reproduced. In the second part of the session, Elodie changed her strategy. The time devoted to the image observation was longer, 16 seconds as a maximum (for the last image) and the use of the *restart button* was rare (none for the last image). Her strategy seems to be based on a precise analysis of the image. The evolution of the average number of clicks on the *restart button* for the whole group shows that this use decreased during the session. This shows that a majority of students shifted a

trial and error strategy to a strategy based on the use of the principles of stratigraphy. The students' answers to the questionnaire confirm this conclusion.

c. Transfer of knowledge

At the end of the session, 20 students from the 24 who passed the final test were able to identify the chronology of geological events on an outcrop's photograph, but only one of them was able to justify his/her response and 4 gave an incomplete explanation. Playing with the game led the students to learn how to identify the chronology of geological events, but they were not able to articulate the knowledge that they used. When they answered the questionnaire, several students themselves expressed that they were reluctant to consider that they had learned something by playing: "*It was fun, but, without the help of a teacher, one cannot really learn something*". The fact that students are often reluctant to consider that they can learn by gaming has been observed in different studies (Egenfeldt-Nielsen, 2007).

4) CONCLUSIONS AND IMPLICATIONS

The design of the gameplay has a significant impact on the learning process. The strategy used by the students is, at a preliminary step, a trial and error strategy based on chance. The students shift to a strategy that involves the knowledge that has to be learnt, if the design of the software disqualifies this trial and error strategy. Starting from this point, a game, as a *didactical milieu*, can be used by the students to assess their decisions and chosen strategy and, therefore, can help them to be autonomous (Sanchez, 2011). Indeed, being autonomous means that the learner/player gets the opportunity to assess his/her strategy by her/himself and then decide if a given decision or action is relevant or not. Assessing implies getting feedback and it is clear that feedback is a crucial element in a game. Therefore, game-based learning results from interactions and we can state that it is worthwhile to adopt a point of view that considers games as situations rather than artifacts (Sanchez & Jouneau-Sion, 2010). Thus serious games are *spaces of reflexivity*, where the learner/player can assess his/her way of thinking and acting. Starting from this point, the term *serious play* is more relevant than the term *serious game* to describe this type of educational practice.

By gaming, the students can develop scientific knowledge. This knowledge is embedded into the game. The students can play with this scientific model, explore the different consequences of their choices and identify properties of the model. The relevance of the scientific model embedded in a game is an important issue to teachers.

The results also indicate that the challenge faced by the students when playing must be inside their zone of proximal development (Malone & Lepper, 1987; Vygotski, 1934). Not all the students managed to succeed in reproducing the images. The design of the game must take into account the necessity to develop students' self confidence in their capability to achieve the challenge.

Our conclusion is that serious games can be implemented in the classroom to teach scientific concepts. Nevertheless, one should expect the learning to consist mostly of procedural knowledge. Indeed, there is a difference between "trying to master the rules of the game and recognizing the ways those rules structure our perception of reality" (Jenkins, Clinton, Purushotma, Robison, & Weigel, 2006). The students do not develop declarative knowledge without reflection and debriefing (Garris, Ahlers, & Driskell, 2002). Some students failed at reproducing the images because the challenge was too difficult. This result emphasizes the importance of the teacher for helping the students to be aware of the implicit knowledge that they use in a specific situation in order to solve a

specific problem. This step, called *institutionalization* by Brousseau (Balacheff, Cooper, & Sutherland, 1997; Brousseau, 1998) and underlined by Habgood (Habgood, 2007), consists in pointing out that the contextualized and personal knowledge used for gaming is universal and scientific.

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INFLUENCE OF CONNECTIVISM ON SCIENCE EDUCATION WITH EMPHASIS ON EXPERIMENTS

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Abstract: The paper presents research results of connectivistic influence on science education with emphasis on experiments. Fast ICT development influences science teaching and learning without us realising this. Implementation of science experiments is also strongly influenced by ICT. Thus a need occurred to examine these connectivistic influences on science education. This study describes a research which focussed on the following issues: identification of connectivistic factors and determination of the extending of their influence on science education; creation of connectivistic educational tools and techniques in science education; implementation of connectivistic education tools and techniques into science teaching and learning and science teachers training. School experiments namely the changes in their form and role in science education came under scrutiny. With the aid of the created research method, the collaborative action research based on ICT efficiency of connectivistic tools and methods in science education was researched and confirmed.

Keywords: action research; connectivism; ICT; science education; science experiments.

1 BACKGROUND, FRAMEWORK, AND PURPOSE

Science education is affected by the fast development of information and communication technologies (hereinafter ICT). The use of computers in the operating of school experiments and processing of observed results has been taken for granted. The Internet is becoming an ever more significant source of information including gaining data from distant laboratories. Records of experiment may be easily taken by digital and video cameras and further computer processed. Special computer software allow for animation, modelling and simulation of experiments. The use of the Internet as a communication network gives the students a whole number of options for information sharing, discussions, common problem solving, etc. We may anticipate creation of other significant ICT applications (holographic projection etc.).

ICT is being used by teachers as well as by students. ICT significantly becomes involved in teaching through the use of projectors, interactive boards, computer processed technology teaching elements including experiments etc. But there are differences between teachers´ and students´ attitudes towards ICT. D. Oblinger and J. Oblinger (2005) describe today's students as the Net Generation (Net Gen), who have grown up with widespread access to ICT and have spent their entire lives surrounded by and using computers, videogames, digital music players, video-cams, cell phones, and all the other toys and tools of the digital age. According to the above-mentioned authors, the Net Generation has some features which are different from previous generations and which affect their education. Here are the ones that influence instruction most:

▪ The Net Generation often intuitively uses a variety of ICT without an instruction manual so their understanding of the technology may be shallow.

▪ The Net Generation is more visually literate than previous generations, but because of the availability of visual media, their text literacy may be less well developed than the literacy of previous cohorts. Most students (73 %) prefer to use the Internet to libraries for research and they know how to find valid information on the Web (Online Computer Library Center, 2002). However, they realize that the Web does not meet all their informa tion needs.

▪ In connection with playing a game or responding the Net Generation sometimes prefers speed to accuracy. They do multitask, move quickly from one activity to another and sometimes perform them simultaneously.

▪ Most Net Generation learners prefer to learn by doing rather than by being told what to do. Net Gen students learn well through inquiry - by exploring for themselves or with their peers. This exploratory style enables them to retain information better and to use it in creative, meaningful ways (Tapscott, 1998).

▪ The Net Generation often prefers to learn and work in teams. A peer-to-peer approach, where students help each other, is common as well. In fact, Net Generation learners consider peers more credible than teachers in terms of determining what is worth paying attention to (Manuel, 2002).

Other authors also state that children growing up with modern information technology are fundamentally different from previous generations of learners and express it using special naming such as the Nintendo Generation, Millennials, Digital Natives or Generation Z.

The fact that today's students are named by various above mentioned names brings along unique learning style preferences and worldviews. The above mentioned findings have led to the origin of a new educational theory – connectivism as "a learning theory for a digital age". Its founder, G. Siemens (2005) recommends extending the currently existing educational theories of behaviourism, cognitivism and constructivism. Constructivism as the currently accepted educational theory suggests that students create knowledge as they attempt to understand their experiences. Siemens states that learning is a network phenomenon, influenced (aided) by socialization and technology.

We continue to consider the principles of constructivism in science education fully valid and efficient which is confirmed by researches (Trna, Trnova & Vaculova, 2010) etc. Crucial impulses brought about by connectivism have to be accepted and examined: "Learning is no longer an internal, individualistic activity. Education has been slow to recognize the impact of new learning tools and the environmental changes. The ability to learn what we need for tomorrow is more important than what we know today. When knowledge, however, is needed, but not known, the ability to plug into sources to meet the requirements becomes a vital skill. As knowledge continues to grow and evolve, access to what is needed is more important than what the learner currently possesses" (Siemens, 2004). Returning back to the features of today's learners it is possible to recognize the reflection in the first principles of connectivism which were established by G. Siemens:

▪ Learning and knowledge rests in diversity of opinions.
▪ Learning is a process of connecting specialized nodes or information sources.
▪ Learning may reside in non-human appliances.
▪ Capacity to know more is more critical than what is currently known.
▪ Nurturing and maintaining connections is needed to facilitate continual learning.
▪ Ability to see connections between fields, ideas, and concepts is a core skill.
▪ Currency (accurate, up-to-date knowledge) is the intent of all connectivistic learning activities.
▪ Decision-making is "itself" a learning process. Choosing what to learn and the meaning of incoming information is seen through the lens of a shifting reality. While there is a right answer now, it may be wrong tomorrow due to alterations in the information climate affecting the decision (Siemens, 2005, p. 5).

Science education is also influenced by connectivism and it would be suitable to examine possible connectivistic influences on science and technology education. Our research is concerned with this problem and is focused on the impact of experiments.

2 RATIONALES

Today science education plays an important role in educational systems and in many systems it has the goal of enhancing scientific literacy in students (American Association for the Advancement of Science, 1989), but the interest of students in science has been significantly decreasing. This negative situation has many causes and factors but based on the above mentioned text the way science is taught in schools and different learning style of today's learners are the main ones. In this context it is necessary to consider how to change teaching methods and increase students´ motivation for science. This study is a start towards alleviating these factors, and also increases the familiarity of ICT use for collaborative work among teachers and trainers across the world. Our core idea is to use ICT for the dissemination and upgrading of ideas, curricular materials and effective teaching methods amongst teachers. Connectivistic ideas of sharing knowledge can be applied even to teachers.

To increase the interest of students in science it is necessary to respect the stated generation differences and understand what they prefer, what they are interested in, how they learn. Like all students, they learn more effectively when taught in accordance with their learning style preferences and when their worldviews are acknowledged. So it is necessary to change teaching methods and materials to accommodate the Generation learners better and to correlate them with improvements in students' attitudes and performances. Therefore the need arose to examine possible connectivistic influences on science education. Our research is focused on the following issues:

(i) Identification of connectivistic factors and determination of extend of their influence on science education.
(ii) Creation of connectivistic educational tools and techniques in science education.
(iii) Implementation of connectivistic educational tools and techniques into science teaching/learning and science teachers training.

To narrow the investigated issue we focussed on the implementation of experiments.

3 METHODS

Teachers need research-based innovative educational methods for the upgrading of their teaching. The motivation of students and teachers in science education is the core of up to date teaching/learning. A very urgent task for educational research is to find appropriate educational methods and tools which have to be implemented into teachers' training and then in teaching/learning science. To monitor the set out connectivistic factors, we used a method of a design-based research. It is a development research. This research differs from other types of researches. Unlike the empirical research, hypothesis and research questions are not determined, but the problem is defined to be solved. Design-based research is a new trend in educational research. The used methodology can be described as a cycle: analysis of a practical problem, development of solutions, iterative testing of solutions, reflection and implementation. This methodology was implemented into our research. The scheme compiled by T. C. Reeves (2006) (see Figure 1) presents a comparison between the design-based (development) research and empirical research.

EMPIRICAL RESEARCH

Hypotheses based upon Observations and/or Existing Theories	Experiments Designed to Test Hypotheses	Theory Refinement based on Test Results	Application of Theory by Practitioners

Specification of New Hypotheses

DEVELOPMENT RESEARCH

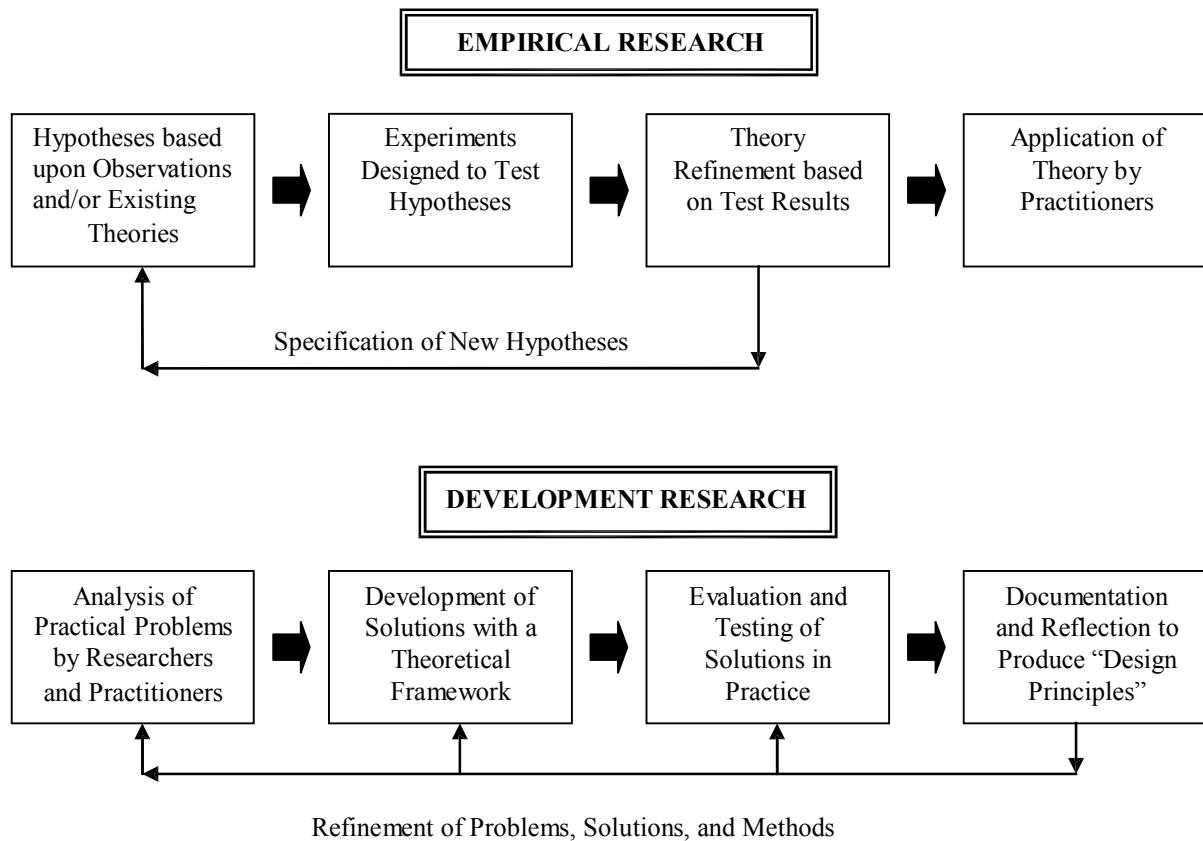| Analysis of Practical Problems by Researchers and Practitioners	Development of Solutions with a Theoretical Framework	Evaluation and Testing of Solutions in Practice	Documentation and Reflection to Produce "Design Principles"

Refinement of Problems, Solutions, and Methods

Figure 1. Empirical and development approaches to IT research (Reeves, 2006)

The core of design-based research is to focus on the creation of a new product. This research offers solutions to problems that have only been solved partially so far and relevant instruments and methods (Järvinen, 2004). The main advantage of the design-based research is its close connection with educational practice. Many results of other researchers are considered as separate from practice and are not understood by teachers. The basic principle and advantage of the design-based research is the close cooperation between researchers and teachers, which is a prerequisite of direct use of the research outputs in everyday practice.

The above-mentioned reasons led us to use design-based research to address the issue of the implementation of connectivism into science and technology education. These methods were created within the frame of collaborative action research based on ICT which can be used as a vehicle for international cooperation with effective exploitation of ICT. Sufficient methods/tools for the research objectives were:
(i) Factor analysis
(ii) Didactic analysis and development of connectivistic teaching techniques and tools
(iii) Collaborative action research based on ICT (Trna & Trnova, 2010) for verification of efficiency of developed connectivistic teaching/learning techniques and tools
Data generating methods were available such as through the use of questionnaires, observations, interviews, tests, students' and teachers' portfolios. Collaborative action research based on ICT was carried out in the following form: it was carried out on-line in two classes, one class in the Czech Republic and the second one in Portugal; it was prepared and managed by two cooperating teachers in the Czech Republic and in Portugal; teaching was carried on at the same time with the use of on-line communication (Skype etc.).

4 RESULTS

(i) + (ii) We have discovered several connectivistic factors that show today in the teaching of science and application of experiments: These include namely:

- Computer control of experiments and computer processing of measured data
- Getting of manuals for experiments from the Internet
- Digital recording and web presentations of experiments
- Knowledge sharing and distribution across a network
- Creation of learning structures using networks etc.

We have developed the set of connectivistic teaching/learning techniques and tools applicable primarily in implementation in ICT based collaborative action research:

(a) Application of a single communication language (English): All students have to be acquainted with English terminology also in science teaching (English descriptions of experiments etc.).

(b) Application of ICT communication technologies: Both students and teachers have to command ICT, namely their on-line variants. A web portal with curricular materials has been created which was accessible to students and teachers. The portal contained descriptions of experiments, worksheets, advice to students, etc.

(c) The use of cooperating students' knowledge: both cooperating classes of students made their own experiments the results of which they mutually communicated with belief that they were carried out correctly. Thus, knowledge of others was utilised in a network. In accordance with the ideas of connectivism acquired knowledge can be considered as connective knowledge. Connective knowledge requires an interaction. More to the point, connective knowledge is knowledge of the connection (Downes, 2005).

(d) Creation of communication connections: Students of one class carried out experiments under the on-line instructions of the cooperating partners. Thus the students were creating the skill how to gain the necessary knowledge and skills.

(iii) We used collaborative action research based on ICT. The "action" factor was collaboration among teachers and students from Portugal and the Czech Republic to upgrade teaching and learning using ICT and the innovative school experimentation. Students were involved in the process of learning and were also encouraged to play a teaching role with respect to their peers. The topic chosen was "photosynthesis" by the use of criteria: position of the topic in the curriculum of the countries, importance of the topic for students' cognitive development, and the level of interest for students. The factors considered for the selection of students were age and ability. It was decided that the students should be approximately the same age, promoting an interest to collaborate students. That is why were selected students of intact classes from secondary schools and 15-16 years of age. They needed to be able to communicate in the English language and had skill in the use of ICT (email, ICQ, Skype, and video-conferencing). For this study, teachers prepared a schedule of their own and their students´ activities for each of the collaborative lessons. The teachers collaboratively developed worksheets, power-point presentations, videos, experiments, learning tasks, etc. Reflection was a very important part of this research.

Pre-test and post-test: Pre-test data was gathered about what students already know about the learning focus in order to ascertain those changes in students´ knowledge and skills. Below is one example of pre-test and post-test that focused on one aspect of this work (see Table 1).

Questionnaire: Students completed such a questionnaire that focused on their reflections on this innovative bilateral collaboration and ICT use. Their answers indicate very high levels of both motivation and engagement with the educational process; they learnt a great deal (see Table 2).

Students´ view of teachers´ work in on-line environment and their ability to manage unusual instruction is also very interesting (see Table 3):

Table 1. Pre-test and post-test findings

Pre-test findings:		
Statement	*Correct answers (%) Czech students*	*Correct answers (%) Portuguese students*
In winter, most plants live of the reserves they accumulated during the summer.	56,2	44,4
Post-test findings:		
The plant stores glucose for later use in seeds, roots and fruits.	87,4	81,5

Table 2. Responses by Portuguese/Czech students

In the statements listed below are some of the aspects related to the activities shared with your Czech colleagues. Choose the option which best expresses your opinion.					
N=27/21	*Disagree*	*Partially Agree*	*Agree*	*Strongly Agree*	*No opinion*
The partnership helped you to better understand certain aspects of this topic.	*7%* *0%*	*33%* *29%*	*42%* *47%*	*14%* *19%*	*4%* *5%*
You would have achieved the objectives of this topic better by interacting only with your classroom classmates.	*33%* *29%*	*52%* *29%*	*4%* *29%*	*4%* *0%*	*7%* *13%*

Table 3. Responses by Portuguese/Czech students

Your teacher's performance (on the aspects listed below) contributed to learning the topic in an online environment. Choose the option that best expresses your opinion.					
N=27/21	*Disagree*	*Partially Agree*	*Agree*	*Strongly Agree*	*No opinion*
The teacher showed enthusiasm in sharing experiences between students from both countries.	0% 0%	4% 14%	33% 33%	63% 48%	0% 5%
The teacher demonstrated a capacity to motivate students in this topic.	0% 0%	7% 19%	63% 43%	30% 33%	0% 5%
The teacher demonstrated dynamism to conduct the present activities.	0% 0%	7% 38%	41% 33%	52% 24%	0% 5%
The teacher's interaction and monitoring of students´ on-line work was effective.	0% 0%	11% 14%	33% 48%	56% 33%	0% 5%
The teacher encouraged interaction both within and between groups.	0% 0%	11% 19%	41% 43%	48% 24%	0% 14%

5 CONCLUSIONS

The main outcomes of the research and implementation of connectivistic techniques and tools into science school experimentation:

■ Strong motivation of students and teachers by communication with colleagues in other country, new information, applications of new knowledge, new personal contacts etc.

■ Exchange of experience between teachers (experiments etc.).

Teachers' and students' improvement of skills to use ICT and English language .

> Gaining of collaboration competencies between teachers and among students.
> Team collaboration among students and teachers.
> More effective acquisition of science knowledge and skills.

The form and role of experiment in science education has been changing which has to be further examined. With the help of design-based research, suitable teaching tools and techniques have to be created for teachers to implement the experiment in teaching in the most efficient way (Hodson, 1988). We may anticipate a growing importance of simple experiments the students and teachers will creatively work with using ICT. Our research results indicate that students learned with interest, and their knowledge and skills were better than would be expected using standard methods free of connectivism. On this basis, these connectivistic tools and techniques produced very positive outcomes for students and teachers-action researchers.

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THE STATES-OF-MATTER APPROACH (SOMA)
TO HIGH-SCHOOL CHEMISTRY:
TEXTBOOK AND EVALUATION BY TEACHERS

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Abstract: Chemistry, as a high-school subject for all, should aim to supply students with scientific and chemical literacy (including chemical culture), to cultivate higher-order cognitive skills, and to be a useful, interesting, and enjoyable subject. A chemistry programme for all students in grades ten and eleven (ages 15-17) that was proposed in Greece some years ago, introduces chemistry through the separate study of the three states of matter [the *states-of-matter approach* (*SOMA*)]. There are three major units in the programme, namely: (A) Air, Gases, and the Gaseous State, (B) Salt, Salts, and the Solid State; (C) Water, Liquids, and the Liquid State. Following the proposal, a textbook was written that adopted SOMA. The book was evaluated by four experienced upper secondary chemistry teachers, (and one university chemistry professor)**.** The evaluation examined the following dimensions of scientific and chemical literacy: cognitive domain (learning), affective domain (satisfaction), relevance to students' life (chemistry and life), and higher-order cognitive skills (HOCS). The teachers found the book complete, dealing with many matters, and its level was advanced (difficult in some cases). SOMA was judged very original, having a logical flow of the material, and in general the evaluators liked it. In addition, the book fulfills, in general, the aims of chemical literacy and chemical culture, is relevant to students' life, and it can cultivate HOCS in students. Finally, we note the expressed reservations and suggestions for improvement.

Keywords: high school chemistry, states-of-matter approach (SOMA), chemical literacy, chemistry textbooks, evaluation of textbooks

BACKGROUND, FRAMEWORK, AND PURPOSE

Chemistry is regarded as a difficult subject for students. The intrinsic nature of the subject and the difficulties associated with the process of human learning are held responsible for this difficulty (Johnstone, 2000). Johnstone has proposed the three-level structure of modern chemistry: the *macro* and tangible level, the *symbolic* and mathematical or *representational* level, and the molecular and invisible or *submicro* level. The psychology for the formation of chemical concepts at the submicro level is quite different from that of the macro/'normal' world.

Chemistry, as an upper-secondary school subject for all, should aim to supply students with chemical literacy and chemical culture, to cultivate higher-order cognitive skills/HOCS (such as critical thinking, problem solving, evaluative thinking and decision making) (Zoller & Tsaparlis, 1997), and to be a useful, interesting, and enjoyable subject. There are various levels and expressions of scientific literacy (Shwartz et al. 2006, and references therein). One categorization distinguishes the following three levels: *practical or functional literacy* is the lowest level, and refers to the ability of a person to function normally in his/her daily life as a consumer of scientific and technological products, such as food, health, and shelter. *Civic*

literacy (or literacy as power) refers to the ability of a person to participate wisely in a social debate concerning scientific and technologically related issues. Finally, *cultural or ideal literacy* includes an appreciation of the scientific endeavor, and the perception of science as a major intellectual activity.

A chemistry program for all students in the tenth and the eleventh grade (ages 15-17) was proposed in Greece some years ago, and introduced chemistry through the separate study of the three states of matter [the *states-of-matter approach* (SOMA)] (Tsaparlis, 2000). SOMA claims to be consistent not only with a *logical* but also with a *psychological* approach to introductory chemistry. It also was conceived so that to deal with many aspects of scientific and chemical literacy.

There are three major units in the programme, namely: A) *Air, Gases, and the Gaseous State*, (B) *Salt, Salts, and the Solid State*; (C) *Water, Liquids, and the Liquid State*. Following the proposal, a textbook was written that adopted SOMA. The aim of this proposal is to present the book as well as the results of its preliminary evaluation by experienced chemistry teachers.

With the first three major units of SOMA, an original approach to chemistry is attempted through the three states of matter. Table 1 outlines the contents of the book.

Table 1: The contents of the SOMA textbook.

UNIT A: Air, Gases, and the Gaseous State	**UNIT C: Water, Liquids, and the Liquid State**
A 1 the atmospheric air	C 1 role of liquid state for life
A 2 atoms and atomic structure	C 2 temperature range for the liquid state
A 3 molecules and molecular structure	C3 intermolecular forces (Van der Waals, London)
A 4 the chemical reaction	C 4 water - hydrogen bonding
A 5 oxygen and inert gases	C 5 bromine and mercury: the only liquid elements
A 6 the ideal gas and its state equation	C 6 organic liquid substances and compounds (diesel fuel, petrol, alcohols, ethers, aldehydes, ketones, acids, esters)
A 7 hydrocarbons and combustion reactions	C 7 solutions, aqueous solutions of ionic compounds, double displacement reactions molarity
A 8 air pollution, greenhouse effect, depletion of ozone layer	C 8 colligative properties of solutions
	C 9 acids and bases - chemical reactions in aqueous solutions
UNIT B: Salt, Salts, and the Solid State	C10 drinking water, water quality, water purification, waste water treatment, water pollution, acid rain
B 1 salt and the crystal structure	
B 2 salts, metal oxides, and metal hydroxides	
B 3 molecular solids	
B 4 metals	
B 5 solid waste and its management; recycling of solid materials (metals, glass, paper, plastics)	

The introduction of the gaseous state first was based on the following facts: (a) being the simplest, it is the best understood by scientists; (b) being macroscopically 'non-concrete' for most students (a misconception), it is the most suitable prelude to the study of the invisible submicrocosmos of atoms and molecules; (c) the elements and compounds which are, under

usual conditions, in the gaseous state have small and simple molecules [we work with only few non-metals (H, O, N, halogens, and noble gases), and compounds (H_2O, O_3, NH_3, NO_x, CO, CO_2, gaseous hydrocarbons, H_2S, SO_2, HCl)]; (d) we start with the covalent bond (Johnstone, 2000; Johnstone, Morrison, & Reid, 1981); neither ions nor the ionic bond are necessary (the ionic bond and the periodic table are introduced in the unit of solids); in the case of the ideal gas, intermolecular forces are absent (but mention of real gases should be made); (e) the study of organic compounds is introduced early (Johnstone, 2000; Johnstone, Morrison, & Reid, 1981). In this way, some integration of inorganic and organic chemistry is achieved. For more information about *SOMA*, see Tsaparlis (2000).

Note that a follow-up course (for the eleventh grade) completes the "*Chemistry for General Education*" course. This course includes the following chapters: (1) overview of organic chemistry; (2) polymers and plastics; (3) medicines (drugs); (4) biomolecules; (6) food; (7) energy; (8) chemistry, the earth, and the space; (9) chemistry as a continuously developing science. (Chapter 7 covers electrochemistry, nuclear chemistry, and alternative forms of energy.)

A sample page from the book is shown in the appendix. An extended excerpt can be downloaded from the following Internet address:

http://www.parsel.uni-kiel.de/cms/fileadmin/parsel/Material/Ioannina/neu1/Salt_7_-SOMA2.pdf

These texts have been translated from Greek into English by the first author of this article.

METHOD

The role of the curriculum is crucial in the educational systems. Textbooks are written in conformity with the curriculum; hence the role of the textbook is also crucial in the teaching process. It is natural then that the evaluation of textbooks is considered as a necessary condition for the upgrading of the provided quality of teaching.

The SOMA textbook was subjected to a preliminary evaluation by four experienced upper secondary chemistry teachers (plus one university chemistry professor). Three of the teachers were male and one female. One teacher had obtained a graduate diploma in science education (this teacher belonged to the research group of the first author).

When the teachers had completed studying the book, we took structured interviews with them, during which they were asked to answer a number of questions concerning their impression, comments, suggestion for improvements, etc. taking also into account the existing state textbooks for chemistry for general education of tenth and eleventh grades. A second group of questions concerned if the book fulfills the aims of chemical literacy and chemical culture, and if cultivates HOCS in students.

The evaluation is in congruence with the main levels of scientific and chemical literacy (Shwartz et al. 2006). In particular, the above questions can be classified according to the following four dimensions: *Cognitive domain* (learning); *Affective domain* (satisfaction); *Relevance* to students' life (*chemistry and life);* HOCS.

A number of extra questions were obtained from the literature and concerned specific aspects of chemical literacy (Shwartz et al. 2006). These referred to (a) general scientific ideas, (b) features of chemistry (key-ideas).

RESULTS

Cognitive domain (learning)

- The teachers found the book complete, dealing with many matters, and its level was assumed to be advanced (difficult in some cases).
- SOMA was judged very original, having a logical flow of the material.
- All liked the integrated coverage of inorganic, organic, and physical chemistry.

On the other hand, there were some reservations regarding SOMA and/or the book:

- The approach was found good, but quite unusual.
- The book contains a number of difficult concepts (e,g. Millikan's experiment, atomic emission spectra, ΔG, enthalpy, phase diagrams, etc.).
  [*Authors' comment:* Most of these are placed inside boxes, and they are not essential – the teacher can skip this material without damaging the flow of the content. On the other hand, their presence provides for fuller coverage and global knowledge.]
- All agreed that the level of the book is advanced, and that it will be difficult for the average student.

Affective domain (satisfaction)

- In general the evaluators liked the book.
- They all liked its format/lay out.

Relevance to students' life (chemistry and life)

The teachers found very good and complete the practical part of the book (dealing with applications and connections to life). In addition, they were asked to comment on the following features were explicitly stated by the researcher during the interviews with the teachers:

- Importance of chemical language for the explanation of everyday phenomena and their uses by people as consumers of new products and technologies, in decision making, and in their participation in a social discussion relevant to issues where chemistry is involved.
- Relations between development of chemistry and social processes.
  [*Authors' comment:* These aspects are served in part by the book. More to this should contribute the follow-up course for the eleventh grade.]

Higher-order cognitive skills

According to the teachers, the book can contribute to the development of these skills. However, the lack of questions and problems was judged as a problem.

[*Authors' comment*: The book needs indeed the inclusion of questions and problems that will contribute to the development of scientific literacy and HOCS.]

Specific questions on chemical literacy

General scientific ideas (these ideas were explicitly stated by the researcher during the interviews with the teachers)*:*

- Chemistry is an experimental science.
- Chemists carry out research and propose theories to explain the world.

These ideas can be achieved with experiments that should be included in the book. According to the teachers, there is need that the book is supplied with a practical part (a laboratory guide).

Features of chemistry (key ideas) served by the book. According to the teachers, the following features are served by the book (these features were explicitly stated by the researcher during the interviews with the teachers):

- Chemistry attempts to explain macroscopic phenomena in terms of the molecular structure of matter.
- Chemistry studies the dynamics of changes and reactions.
- Chemistry studies the energy changes that accompany chemical reactions.
- Chemistry uses a special language – a chemically literate person does not have to know this language, but he/she should be able to appreciate the contribution of the chemical language to the development of this science.
- Chemistry contributes to the understanding and explanation of life on the basis of chemical structure and processes in living organisms.
  [*Authors' comment:* This aspect is covered by the biology course - but also note that a chapter on biomolecules is suggested to be included in the follow-up chemistry course for the eleventh grade.]

Finally, the teachers made suggestions for improvements. We have mentioned already the need for addition of a laboratory guide, and of questions and problems. Most teachers thought that more organic chemistry would be necessary. Organic chemistry is dealt with more systematically and more fully in the proposed follow-up course (see above). Of particular interest is a suggestion by the university professor that the Internet is an endless source of scientific information, facts, and data, hence there is no need to burden anymore modern textbooks with details and facts that can easily be found on the Internet; this will contribute to the drastic shortening of text length.

CONCLUSIONS AND IMPLICATIONS

SOMA combines the logic of chemistry with the psychology of learning (Johnstone, 2000). It could provide scientific and chemical literacy (including chemical culture) to all students, as well as make them appreciate chemistry as an interesting and enjoyable subject, and above all help them to realize its usefulness for their future career and life. We hope that *SOMA* has the potential to give school chemistry a new impetus and status.

SOMA is close to a formalist approach to science teaching. It is possible to combine it, however, with other available context-based material. In this spirit, we have combined SOMA with a recent European Union project, namely '*Popularity and Relevance for Science Education for scientific Literacy*' (PARSEL). PARSEL has developed a number of science modules for secondary education that are available freely on the Internet.[1] Two of the modules, one on carbon dioxide and carbonated beverages and the other on salt, could be used within the *SOMA* units on gases and on solids respectively (Tsaparlis, 2008).[2] A third module on water is under preparation, and that will be suitable to use within the SOMA unit on liquids.

NOTES

[1] The PARSEL Internet site is at the following address: http://www.parsel.uni-kiel.de/cms

[2] The SOMA module on carbonated beverages ("The gas we drink: Carbon dioxide in carbonated beverages") is available in English and in Greek. The module on salt ("Salt: the good, the bad, and the tasty") is available in English, in German, and in Greek. These modules are available at no charge at the following Internet address:

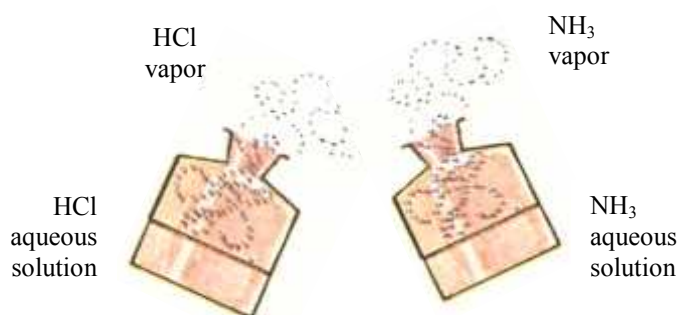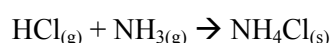http://www.parsel.uni-kiel.de/cms/index.php?id=modules

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**APPENDIX: A sample page from the book from Unit A (Air, Gases, and the Gaseous State)**

A 4 CHEMICAL REACTIONS

A 4.1 Chemical changes – Chemical reactions

Often when we bring into close contact between themselves one or more substances (often under the usual conditions of temperature and pressure, but also in different conditions, e.g. higher temperature and/or pressure) one or more changes take place. As a result, one or more new substances are formed, with simultaneous disappearance of part or of the whole of the starting substances. As an example, if we bring into contact gaseous *hydrogen chloride* with gaseous *ammonia*, a new substance is formed, namely the solid *ammonium chloride*:

$$HCl_{(g)} + NH_{3(g)} \rightarrow NH_4Cl_{(s)}$$

HCl vapor

NH₃ vapor

HCl aqueous solution

NH₃ aqueous solution

The above change is called **chemical change** or **chemical reaction.** A single substance can also undergo a chemical change; for instance, gaseous *hydrogen iodide*, if heated at $550^{o}C$ in a closed vessel, decomposes into its constituent elements, *hydrogen* and *iodine*:

$$2HI_{(g)} \rightarrow H_{2(g)} + I_{2(g)} \text{ (at } 550^{o}C)$$
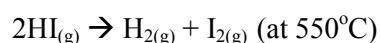
The starting substances are called the **reactants**, while the new substances are called the **products** of the reaction.

There is also the case that a chemical reaction between certain reactants not to take place under usual conditions, but to take place when another substance is present in small amount in the reaction mixture. This extra substance does not change itself during the reaction – it simply makes the reaction possible by its mere presence. As an example, a mixture of oxygen and hydrogen remains unchanged for ever, but reacts vigorously in the presence of platinum (Pt), forming water.

$$2H_{2(g)} + O_{2(g)} \xrightarrow{\text{Pt}} 2H_2O_{(l)}$$
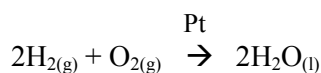
In this case, we say that *the platinum* **catalyzes** *the reaction/***acts catalytically** */ is a* **catalyst** *for the reaction.*

In a chemical reaction, an *interaction* takes place between the molecules of the reactants. The result is that the molecules of the reactants change (by *re-arrangement of the atoms*) into the molecules of the products.

COMPARATIVE EVALUATION OF LOWER-SECONDARY PHYSICS TEXTBOOKS: THE ROLE OF SCIENCE EDUCATION

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Abstract: We examined in actual school practice the effectiveness of an experimental non-standard introductory book to physical science (physics and chemistry) for the seventh grade (first grade of lower secondary school in Greece). The book has been written by science-education researchers, on the basis of principles of science education. In particular, we compared the performance in a relevant test of an experimental group of students ($N_1 = 50$) who were taught two physics lessons (on the 'force' and on the 'weight of a body') from the above book, with the performance in the same test of a control group of students ($N_2 = 50$). who were taught the same topics from the standard eighth-grade physics school book. The study was carried out in four eighth-grade classes of two urban lower-secondary Greek schools. The statistical analysis showed that the non-standard book assisted students more in understanding the taught science concepts. However, due to the marginally small sample size and the very limited number of taught topics, the finding should be considered as a preliminary one.

Keywords: physics textbooks, evaluation of textbooks, science education, force, weight

BACKGROUND AND FRAMEWORK

Teaching can be considered a special form of communication and interpersonal relations between the teacher and the students. The role of textbook is crucial in the teaching process. It ensures this communication and contributes more to the growth of interpersonal relations in the classroom than other teaching tools, such as transparencies, experiments, video, PC, etc. (Armbruster & Anderson, 1991).

The evaluation of textbooks is considered as a necessary and sufficient condition for the upgrading of the provided quality of teaching. However, even though the textbook remains the most important teaching tool, it has not gained its proper place either in the relative research literature or in the educational discussions (Bandura, 1986). On the other hand, the results from relative work (Costa et al., 2000) indicate a limited knowledge on the part of the secondary school teachers about the findings of educational research.

Rationale and Purpose

According to the implications of science education research, modern pedagogy should encourage: (a) the active and constructivist teaching and learning; (b) meaningful and conceptual understanding; (c) the development in students of practical abilities; (c) the connection of science with everyday life; (d) a spiral curriculum; (e) the cultivation of higher-order cognitive skills, such as critical thinking. In principle, the application of such instructional methodologies is primarily the job and responsibility of the teacher, and not so much of the textbook. However, to aid the teacher in this job, and considering

the limited awarenees of educational research by secondary school teachers (Costa et al., 2000), two of the authors of this article, who are active researchers in science education, decided to prepare the experimental material for this programme in the form of a complete textbook, containing experiments, theory, questions, and problems (Tsaparlis & Kampourakis, 2003).

To our knowledge there is only one international physics book that is based on the learning-by-inquiry model, namely the American textbook "*Physics by Inquiry*", written by L.C. McDermott and her physics education group at the University of Washington (McDermott, 1996). However, we had not consulted and threfore not followed this textbook in writing our own textbook. Our book is entitled "Introduction to physical science" (physics and chemistry) for the 7th Grade" (first grade of lower secondary school in Greece), and is based on principles of science education. Table 1 provides ten basic principles that were adopted in writing the textbook (for details see Tsaparlis & Kampourakis, 2000). The book was written, tested, and evaluated some years ago in the context of the project SEPPE of the Greek Pedagogic Institute. The reader can see an example lesson ("Chemical reactions in aqueous solutions", translated from Greek into English by the first author) in the Supplementary Information/Part 3, to a paper by Tsaparlis et al. (2010) or directly at the following web address:

http://www.rsc.org/suppdata/rp/c0/c005354f/c005354fesi.pdf

In this work, we compare the above book (henceforth called 'experimental book' (EB) against the standard lower-secondary school physics textbook for the 8th grade (school book, SB) (Antoniou et al., 2007). At the outset, we must emphasize that by this work we do not intend to check if the one book is superior to the other; after all, we only used selective topics and a particular test; in addition, due to the relatively small sample size and the very limited number of taught topics, the findings should be considered as preliminary.

Table 1: The ten guiding principles in the writing of the textbook.

1. The spiral curriculum.	6. Scientific rigor - correct use of language.
2. Use of experiments, especially experiments that will be carried out by groups of pupils.	7. Connection of science with everyday life and applications - Development of environmental conscience.
3. Focus on meaningful learning - discouragement of rote learning.	8. Active and inquiry forms of learning.
4. Emphasis on simplicity of phenomena and concepts - priority given to concrete examples – delay of treatment of the abstract concepts of molecules and atoms.	9. Taking into account of students' alternative ideas and misconceptions (constructivist teaching).
5. Delay of representations with chemical formulae and equations.	10. Contribution to students' cognitive development, as well as encouragement of critical thinking.

METHOD

Two Greek urban schools participated in the study ($N_1 = 50$ $N_2 = 50$). In each school, the natural class physics teacher taught two lessons (on the 'force' and on the 'weight of a body') from the EB to an intact school class (experimental class, EC); the same teacher taught the same topics from the SB to a different intact class of the same school (control class, CC). The EC and CC were about equivalent, as advised by the class teacher, and as checked by students' average achievement in the first-term physics test. After the teaching, the students of both classes in each school were given the same test for the same period of time (about 20 minutes). Students' answers were graded by the second author. The physics test is shown in the appendix, and consists of three questions. Questions 1 and 2 were taken from the EB (but had been removed from the students' text), while Question 3 was taken from the SB. All questions were demanding and were selected because they tested both for knowledge and conceptual understanding. The small number of questions was directed by the fact that the teachers had only a limited time (20 minutes) to administer the test, because of limited overall available instructional time.

Internal consistency of the test was checked by calculating Cronbach's alpha coefficient. The alpha values were 0.658 for the SB, 0.710 for the EB, and 0.702 for the total student sample. Values form 0.6 to 0.7 are assumed as showing moderate internal consistency, while values higher than 0.7 show higher consistency (Cortina, 1993).

Reliability of the marking was checked by having three experienced teachers first agreeing on a marking scheme and then each one of them marking 15 randomly selected papers. The non-parametric *Spearman* rho correlation coefficient gave values ranging from 0.852 to 0.972. The 15 papers were also marked independently by the researcher who marked all the papers. The correlation coefficient between the researcher's marking and the average marks of the three other markers ranged from 0.849 to 0.983.

Normality of the distributions was checked by means of the Kolmogorov-Smirnov test. It was found that normality was not followed when taking separately each question, but it was followed when taking all questions together. As a consequence, for the comparison of the achievement in all three questions we used the student *t*-test, while for the comparisons of the achievement in each separate question we used the Mann-Whitney non-parametric test.

All statistical calculations were made by using SSSP.

RESULTS

Figure 1 is a box-and-whiskers plot of student performance per question and the average mark of the three questions for the control and the experimental classes. Every box depicts the range of the 50% of middle marks, leaving out the top and bottom 25%. The horizontal line inside a box shows the median. The whiskers show the highest and lowest mark.

Table 2 has the average marks and the corresponding standard deviations for the four classes, the three questions and the average of achievement in the three questions. For question 1 there is a 26.4% difference in favor of the experimental group. For question 2 this difference is only 2.2%, while for question 3 it is 6.8%. Taking the average of the three questions, the experimental group is superior by 11.8%. For the comparison of achievement in the totality of the three questions, the student *t*-test assumed the value of 2.691 ($p = 0.008$), by using both the hypothesis of equal and unequal variance (Table 3). For the comparisons of the achievement in each separate question, the non-parametric Mann-Whitney test gave Z-values equal to 3.586 for question 1 ($p < 0.01$), 0.764 for question 2 ($p > 0.10$), and 3.082 for
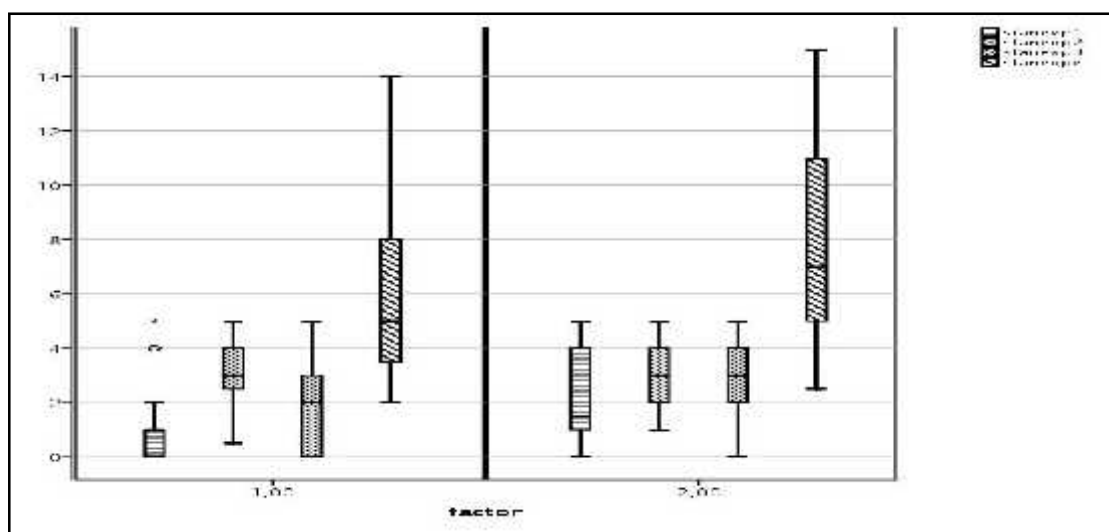
Figure 1. Box-and-whiskers plot of student performance per question and the average mark of the three questions for the control (left-hand side) and the experimental (right hand side) groups.

Table 2: Student achievement per class and per question (mean mark and standards deviations in parentheses (maximum 100). (EC: experimental class; CC: control class)

Class	Question 1	Question 2	Question 3	Average of three questions
EC1 (N=25)	40.0 (39.2)	68.0 (24.0)	41.6 (35.6)	49.9(25.9)
EC2 (N=25)	52.8 (37.0)	56.4 (22.8)	47.2 (31.6)	52.1 (22,0)
Total ECs (N=50)	**46.4 (38.2)**	**62.2 (23.8)**	**44.4 (33.4)**	**51.0 (3.60)**
CC1 (N=26)	13.0 (21.8)	65.0 (19.8)	42.4 (30.6)	40.1 (18.2)
CC2 (N=24)	27.6 (32.2)	54.6 (21.8)	32.6 (31.6)	38.2 (21.3)
Total CCs (N=50)	**20.0 (28.0)**	**60.0 (21.2)**	**37.6 (31.2)**	**39.2 (19.6)**

question 3 ($p < 0.01$) (Table 4). In questions 1 and 3, the differences are statistically significant in favor of the experimental classes at the 1% significance level (s.l.). In question 2, the difference is not significant. For the average of the three questions, the difference is significant at the 1% s.l.

DISCUSSION AND IMPLICATIONS

Question 2 asked students to just draw vectors for the exerted forces, but did not require explanations. On the contrary, questions 1 and 3 asked students to explain their answers, hence they were more demanding. This must have contributed to the considerably higher average student marks in question 2.

Table 3: Comparison of performances for the average of the three questions of the experimental and the control group ($N_1 = 50$, $N_2 = 50$) by means of the t statistic.

	Levene test for equality of variances		t-statistic		
	F	Sign. level	t	d.f.	Sign. level
Hypothesis of equal variances	3.945	0.050	2.691	98.00	0.008
Hypothesis of unequal variances			2.691	94.15	0.008

Table 4: Non-parametric Mann-Whitney test for the separate questions.

	Question 1	Question 2	Question 3
Mann-Whitney U	750.5	1207	811
Z	-3,586	-0,301	-3,082
Asymptotic significance level	0,000	0,764	0,002
Statistical significance	p<0,010 (S)	p>0,10 (NS)	p<0,01(S)

Question 1 had an added problem: from the placement of the three boys in the picture many students made the interpretation that the one boy on the right-hand side was pulling against the force of the two other boys. This is supported by the analysis of interviews taken by a number of students.

In the average of the three questions, there is statistically significant superiority of the experimental classes at the 1% significance level. We conclude that the approach to the concepts of force and weight by the experimental book helped students of the experimental classes more than the approach of the school book.

Finally, we must point out a number of limitations of this study. We only used selective topics and a particular test. Also, due to the relatively small sample size and the very limited number of taught topics, the findings should be considered as preliminary ones. Further study is needed, with more topics, more schools, and more teachers. In any case, we must emphasize that we do not claim by any means that the experimental book (of which authors are two of the authors of this article) is superior to the school physics book for the eighth grade. The authors of the school book are certainly capable and enthusiastic teachers and authors and among them are teachers who have studied physics education. In addition, the experimental group was written with a certain approach which has apparently affected the choice of the particular questions used in this study. If we had used a different test the outcome could have been different. We call the readers therefore to take the above

limitations into account in interpreting the findings of this study. Further research is needed, which would include more lessons, taught by many teachers and in many schools.

In conclusion, the current aims of science teaching in secondary schools can be served better by textbooks that employ methods and approaches that are supported by the findings of science education research. This requires the use of a multitude of methods and approaches. The experimental book that was tested in this study has adopted such an approach and provided evidence that supports the claim that this book contributed to better achievement in the studied topic and test.

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APPENDIX: THE TEST

1. In the figure, each child exerts the same in size force (20 N) on the rope he/she pulls. From the physics point view, are the three forces equal? Explain your answer.
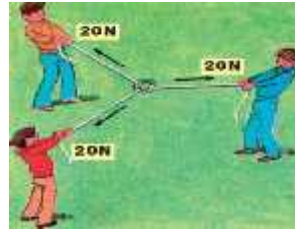
2. In the following pictures, draw the vectors of the forces exerted by: I. The girl's hand on the string. II. The weight-lifter on the weights. III. The earth on the satellite. IV. The magnet on the iron sphere.

3. A schoolmate of yours has this opinion: "A material body has weight when it is on the earth's surface, but it has not weight when it is on the moon's surface". Do you agree? Explain your answer.

WEB-BASED TOOL FOR BASIC CHEMICAL PROBLEM SOLVING IN AN E-LEARNING CONTEXT

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Abstract: In this paper we present a web-based tool which may be used in the didactic treatment of aspects traditionally identified as being a key element in the teaching of chemistry: the solving of simple problems which imply the knowledge of concepts such as mole and amount of substance among others. We have evaluated its use during teacher trainees' first contact with these themes, as a substitute to a classroom session methodology. Good results were obtained. Two homogeneous groups of students with the same level of chemistry knowledge were compared. The group whose learning was based exclusively on the use of the tool without teacher's help, in the end got the same results as the group who received formal instruction from the teacher.

Keywords: Chemical education, E-learning, Web-based tool, Learning object, Problem solving

BACKGROUND, FRAMEWORK, AND PURPOSE

Research in didactics of experimental sciences has traditionally involved the study of the difficulties that certain concepts pose at different educational levels. In the case of teaching chemistry, the key concepts of *mole* and *amount of substance* stand out (e.g., Dierks, 1981; Lybeck et al., 1988; Furió et al., 2002-2006). It seems that the errors in understanding arise from the comparison of the amount of substance with other magnitudes such as mass or volume, or with a number of particles (Avogadro's number). These difficulties are expressed especially in the solving of quantitative problems. Therefore, in many cases the student is incapable of reasoning in terms of proportionality or simple mathematical connections, and learns algorithms or typical problems which he carries out in a repetitive way with little thinking (Gómez-Moliné, 2007; Dahsah and Coll, 2008). Given that generally speaking, overcoming these difficulties depends largely on the direct interaction pupil-teacher, in non-presence teaching contexts the development of materials and methodologies designed to meet that objective is fundamental.

One of the challenges of the application of information and communication technologies (ICT), in the environment of science teaching is the development of adequate teaching tools. Centering on the case of chemistry, the culmination of this evolutionary process is the extended use of hypermedia and of virtual learning environments (e.g., Dori and Barak, 2001; Ardac and Akaygun, 2004; Jiménez and Llitjós, 2008; Maia and Justi, 2009; Own, 2010).

RATIONALE

The tool is a website made up of three multi-linked pages, as is indicated in Figure 1. The main page consists of a concept map in which the main numerical calculations that can be carried out between basic chemical magnitudes, are described. In the nodes of this concept map, concepts such as the number of moles (amount of substance), the mass expressed in grams, the volume in litres, the amount of particles (atoms, molecules, ions….) and the atomic mass units (a.m.u.) appear. These magnitudes are connected by the corresponding

operators; formula weight (FW), Avogadro's number (AN) and the coefficient 22.4, which connects the amount of moles and the volume of an ideal gas in standard conditions of pressure and temperature. Each button that appears on the concept map corresponds to a concept or an operator, contains a hyperlink to one of the other two pages, summing up a total of 13 links from the main page (5 with the concepts one and 8 with that of the operators).

Figure 1: Structure of the website *quimicalcul*.
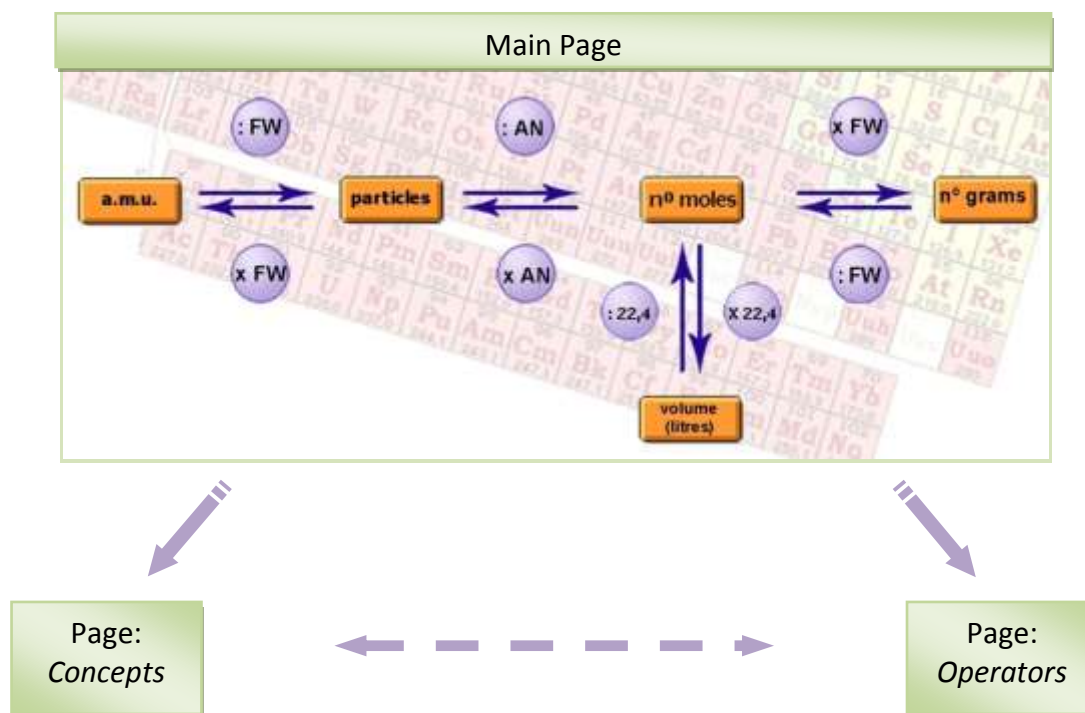
On the page named *concepts*, we include a continuous series of comments for each one of the magnitudes that appear as nodes of the concept map on the *main page*. These comments try to facilitate the understanding of how the concept map works, as well as making the meaning of these concepts more accessible for a beginner student of chemistry.

On the page called *operators*, definitions and comments on the formula weight appear (with atomic and molecular weights integrated within), Avogadro's number (its importance and notes on its historic development), and the coefficient 22.4 (its connection with the ideal gas law). This page also includes on the use of these operators, in the form of small numerical problems already solved, which may be illustrative for the beginner student.

The presentation of the concepts and their connections in the form of just one concept map may bring a series of advantages:

a) In this context, the integration of a series of transformations between magnitudes in which the operators simply multiply or divide may help the student to associate by analogy these calculations with more everyday ones (money, objects which are bought and sold, etc.).

b) Likewise, when they have an overview, the understanding of calculations which require more than one step is made easier. So, for example, the relation between the amount of grams of a substance and the amount of atoms that it contains requires the consideration (explicit or implicit) of two proportions (grams-moles and moles-atoms).

c) The fact that the concept of mole takes up the centre of the concept map, and that the majority of the conversions between magnitudes require "passing through it", is an implicit reinforcement which contributes to the students' understanding of its importance.

However, it would not be satisfactory if learning were limited to correctly carrying out the numerical transformations without a deep understanding of the concepts. So, it is fundamental to have links to the other two pages: *concepts* and *operators*, which would allow frequent consultation of some of the doubtful aspects as well as facilitating access to clarifying examples.

The tool *quimicalcul* has been integrated into a virtual learning environment equipped with the possibilities of the software *moodle* (*ceuandalucia virtual campus*). Therefore, embedded in a content unit, with a group of education students and by means of the platform, so that the teacher carries out his role as guide in learning, is how this tool is adequately used (Figure 2).

Figure 2: Hypertext quimicalcul integrated into the virtual learning environment.

METHODS

Although the preliminary presentation (Vílchez, 2008) and the first details about the efficiency of this tool were moderately positive, we found it essential to collect quantitative data that would contribute to a more objective evaluation. The wide variety and increasing complexity of multimedia resources to teach science make its assessment a task that is not always easy to achieve (Leacock and Nesbit, 2007; Zens et al., 2007; Evans and Leinhardt, 2008). Various approaches may exist according to the interests of different academic communities. In this case, *quimicalcul* is a simple learning object that we have assessed for specific conditions of the educational process.

We have centred on the possibility of using quimicalcul as a substitute to a classroom methodology at the beginning of training in chemistry, in which students come in contact with basic magnitudes and acquire skills in preliminary calculations.

To do this we have used a short, very basic questionnaire consisting of the reasoned solution of 3 small numerical problems which imply the passing of moles to grams (item 1), from grams to moles (item 2) and the passing of grams to molecules (item 3):

> If a molecule of gaseous hydrogen (H_2) weighs 2 atomic mass units, consider how many grams a mole makes up.
> 1) Calculate the number of grams contained in 5 moles.
> 2) Calculate the number of moles contained in 100 gr.
> 3) Calculate the number of molecules contained in 100 gr.
> Justify the answers.

The questionnaire was given to students enrolled in the course *Natural Sciences and its Didactics* within the Primary Teacher Training program at C.E.S. Cardenal Spínola-CEU (affiliated with the University of Seville-Spain). Students were divided into two groups according to the methodology used. Forming part of one or other group was assigned at random in order to control for variables not related to the intervention:

Group-T (N = 29)**:** In this group students followed a traditional classroom method without using the hypertext *quimicalcul.* The teacher presented the concepts, the connections between magnitudes in an explanatory way and examples on numerical calculations were carried out.

Group-Q (N = 23)**:** Students in this group have only used the tool *quimicalcul*, without the presence of the teacher.

In both groups, the intervention was implemented during a one hour session. The students in each group carried out the proposed exercises of the questionnaire at two time points:

1) After coming into contact for the first time with some basic concepts, but without initiating work with numerical calculations (*Pre-Test*);

2) After the one-hour intervention (*Post-Test*): teacher instruction (*group-T*); familiarization and interaction with *quimicalcul* (*group-Q*).

RESULTS

Each item was marked from 0 to 1, assessing not only the numerical results but also the justifications or lines of argument of the answers. Therefore the global marks of the test range between 0 and 3 points. In *Table 1*, the corresponding data (mean of the total score) are shown as well as the results of the statistical comparison tests used.

According to the results of the Mann-Whitney tests there were no significant differences between *T* and *Q groups* in the total pre-test score ($p > 0.05$). We can therefore conclude, that both groups began at the same level (in any case the means are slightly higher in *group-T*). Across the two groups, a clear improvement in the results of the post-test compared with the pre-test can be observed ($p < 0.05$ in the Wilcoxon signed-rank test).

The comparison between the traditional group and the *quimicalcul* one, after the intervention, also indicates that there were no significant differences between groups' post-test scores, according to the Mann-Whitney test ($p > 0.05$). It is also significant how *group-Q* obtains similar results to those of *group-T* in the post-test, even starting from slightly inferior results in the pre-test.

Table 1: Results of the statistical tests of contrast used.

	Pre-test	*Post-test*	Wilcoxon signed-rank test
group-T	Mean = 1.40	Mean = 2.53	Z = -4.21 / p=0.000
group-Q	Mean = 0.97	Mean = 2.56	Z = -3.78 / p=0.000
Mann-Whitney test	U=273.000 / p=0.114	U=276.000 / p=0.243	
Note. As the variables do not fulfil the requirement of normality in their distribution, they are used as statistics of contrast: the Wilcoxon signed-rank test as a substitute of the Related samples T-test and the Mann-Whitney test as a substitute for the Independent samples T-test.			

CONCLUSION AND IMPLICATIONS

We have evaluated the potential of the tool for use in a virtual learning environment like *moodle,* as a substitute for a traditional classroom methodology in solving problems on basic chemical magnitudes in teacher training during the initial phase of the work.

This study shows that *quimicalcul* permits students to get the same results as those achieved with a traditional teaching methodology. This result may be framed within the so called *No Significant Difference Phenomenon* (Russell, 2001), which refers to a type of scientific literature that documents the non existence of significant differences in the results of students who follow alternative education methods. In our case, this "no difference" indicates that *quimicalcul* constitutes a good tool in non face-to-face or distance learning contexts, in the conditions analysed. This aligns with what was found in other investigations which analyse the use of web-based environments as a substitute for traditional teaching methods in science classes at the university level (Lovatt et al., 2007).

As an addition to this work, we are exploring the possibilities of using *quimicalcul* for collaborative learning. As it is embedded in a virtual learning environment it could benefit from the capacities that this offers for interaction among students (forums, wikis).

On a final note, we would like to recommend that teachers to familiarize themselves with this type of tool from their basic training, weighing its advantages and limitations, and thus, appreciating the contexts in which they may be used most favourably.

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A MOBILE COMPUTING SYSTEM DEVELOPED BY DIGITISING THE FORTUNE LINE METHOD

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Abstract: In order to support science learning oriented to conceptual change, we developed a mobile computing system developed by digitising the fortune line method. The theoretical framework for our system is the conceptual ecology model. The system supports the visualisation and sharing of the commitment of numerous learners to multiple ideas.

In addition, we preliminarily introduced the system into Japanese elementary science curricular units and evaluated its possible effect in supporting science learning. Elementary students change their naive concept to a scientific concept after learning in the science curricular unit implemented in the system. The students positively evaluated the system's learning support functions. These results lead us to the conclusion that the system possibly supports science learning oriented to conceptual change.

Keywords: Mobile computing, Conceptual ecology model, Fortune line method

THEORETICAL FRAMEWORK

Conceptual Ecology Model

In science education research, learning science is predominantly viewed as a continual process of conceptual change (e.g., Duschl & Hamilton, 1998). Many science teaching methods and curricula that follow the conceptual change approach place importance on visualisation and the sharing of concepts that individuals carry with them (e.g., Driver, Guesne, & Tiberghien, 1985; Osborne & Freyberg, 1985; West & Pines, 1985).

Various proposals have been made about how to express or describe conceptual change (Chi, Slotta, & de Leeuw, 1994; diSessa, 1993; Vosniadou, 1994). Among these, one of the most widely accepted models by researchers and teachers who aim to promote conceptual change is the conceptual ecology model (Chang, Chang & Tseng, 2010; Posner, Strike, Hewson, & Gertzog, 1982). According to this model, learners' concepts can be described as their ideas and their commitment to these ideas. Therefore, in order to promote conceptual change based on this model, it is essential to allow the visualising and sharing of each learner's multiple ideas regarding a specific learning content and his or her commitment to

these ideas.

Although in past studies, various educational technologies have been proposed to support the visualisation of learners' concepts, including text description, semantic networks and imaging (e.g., Linn, 1998; Cañas, Hill, Carff, Suri, Lott, Eskridge, Gómez, Arroyo, & Carvajal, 2004), no technologies have been proposed to support the visualisation of learners' concepts by expressing them as learners' ideas and commitment to them. To enhance curricula and classroom instruction to promote conceptual change, from the viewpoint of educational technology research, it is necessary to develop technologies that use a model well-accepted by researchers and teachers who aim to promote conceptual change as a theoretical base.

The Fortune Line Method as a Representation of Learners' Commitment to Multiple Ideas

What method is employed for visualising and sharing learners' commitment to multiple ideas? We focus on the fortune line method, which was originally a paper-and-pencil method introduced by White & Gunstone (1992) to the field of science education; it is highly regarded for visualising learners' commitment. For example, Kubota (2003) introduced the method in order to probe students' commitments to their supporting theories into the curricular unit 'heat and current' in junior high school. He analysed when their commitments change and showed the method to be very effective and to have powerful functions. Tonishi & Kubota (2004) developed a series of studies to clarify the meaning and effectiveness of the method as a clinical tool for learning in conceptual change-oriented science lessons based on detailed case analysis and suggested that the fortune line method is effective.

However, it is extremely difficult for the method to support numerous learners in sharing their commitment to multiple ideas (the typical class size is 40 in Japanese schools). We assume that by sharing a fortune line drawn to externalise learners' commitment between students or in the entire classroom, we can activate classroom discourse and promote conceptual change in individual students. Based on this assumption, we have attempted to more strongly promote the sharing of commitment through the digitisation of the fortune line method.

MOBILE COMPUTING SYSTEM

Expression of learners' commitment

The learners can input a line by touching the left 'draw the lines' button and touching the input phase (gray-colored zone) on the main screen (**Figure 1**). The user can input different types of lines by touching the middle 'select the pens' button on the main screen and selecting the appropriate pen on the subscreen .
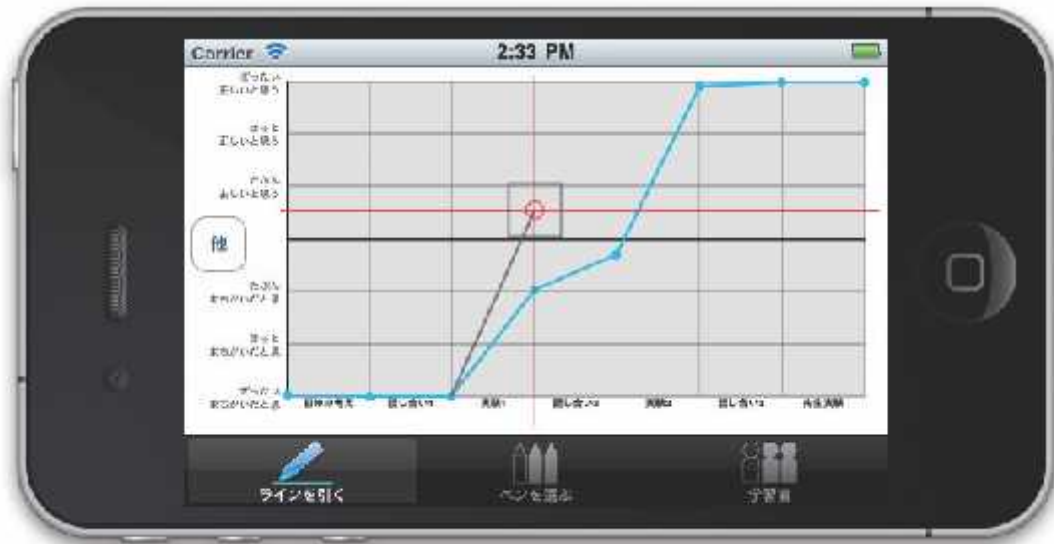
Reference to other learners' commitment

Figure 1: Expression of learners' commitment
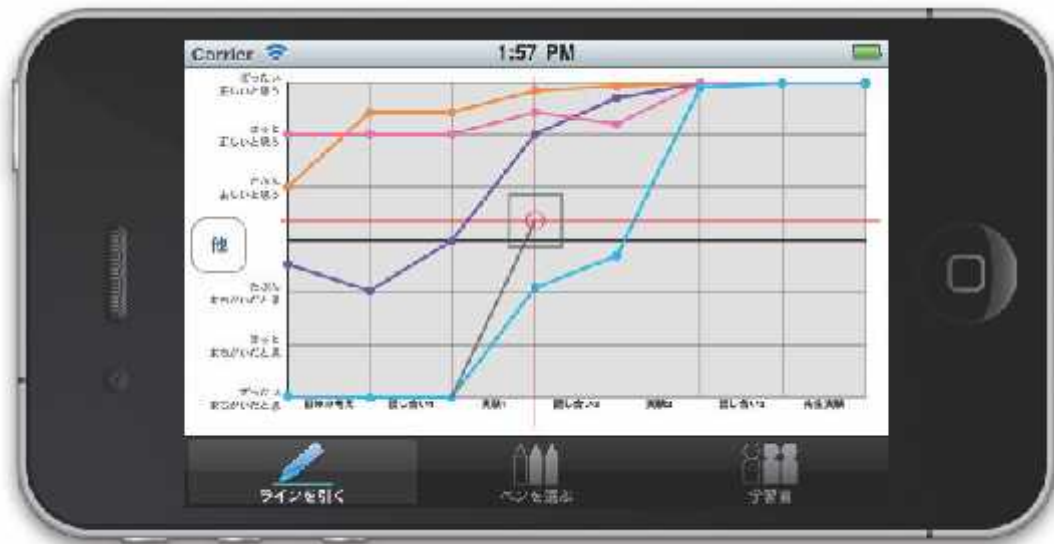

Figure 2: Reference on other learners' commitment

The learners can superimpose several different lines of input by several users on their screens by touching the right 'select the lines' button on the main screen (**Figure 2**) and selecting the group member(s) whose line(s) they wishes to view on the subscreen. Using this function, learners can review the differences between their own and others' commitment to multiple ideas, and can discuss their reasons for changes in their commitment.

EVALUATION OF THE SYSTEM: RESEARCH QUESTIONS

The research questions that guide our evaluation study include the following.
(1) Do elementary students change their naive concept to a scientific concept after learning in

the science curricular unit into which the system was introduced?

(2) How do elementary students evaluate the system's learning support functions?

RESEARCH DESIGN AND METHODOLOGY

Participants

The participants in our research were 114 fourth grade students (nine or ten years old) from three classes. They had not used the system or the fortune line method before the research.

Science Curricular Unit

The curricular unit conducted fourteen periods (one period lasted 45 minutes). The learning content was states of matter, and the goal was to change students' naive concept (not all substances exist in the three states (solid, liquid, and gaseous)) to a scientific concept (all substances exist in the three states) through hand-on experiments and discussion.

Viewpoints of Evaluation

(1) Students' Conceptual Change

To answer research question (1), a pre-test and a post-test were conducted before and after the curricular unit. Each question asked whether the substance existed in solid, liquid, and gaseous forms. In each question, students were given options: 'exist', 'do not exist', and 'I have no idea'. It took them approximately 15 minutes to answer the questions. One point was given to students who answered that all states of a substance—solid, liquid, and gas—'exist'. With 17 substances in total, a perfect score was 17.

(2) Evaluation of Learning Support Functions by Students

To answer research question (2), a questionnaire survey of students was conducted after the curricular unit, wherein nine questions were asked about the effectiveness of expression and reference functions of the system for learning support, in other words, items asking students whether learning activities meant to contribute to conceptual change occurred when they used each function of the system. These items were answered using a four-point Likert scale. The survey took approximately 15 minutes.

DATA ANALYSIS AND RESEARCH FINDINGS

Students' Conceptual Change

Figure 4 shows the results of the pre-test and the post-test. While the average score was between 1.5 and 2.5 for the pre-test (class A, 2.3 ($SD = 2.0$); class B, 1.6 ($SD = 1.9$); class C, 2.0 ($SD = 1.8$)), the average score was between 15.0 and 16.5 for the post-test (class A, 15.2 ($SD = 2.6$); class B, 15.9 ($SD = 3.0$); class C, 16.1 ($SD = 2.5$)). Wilcoxon signed-ranks tests were conducted for each score. It was found that the scores of the post-test were significantly higher than those of the pre-test ($Z = 5.386$ (class A), 5.424 (class B), 5.412 (class C); $p < .01$).
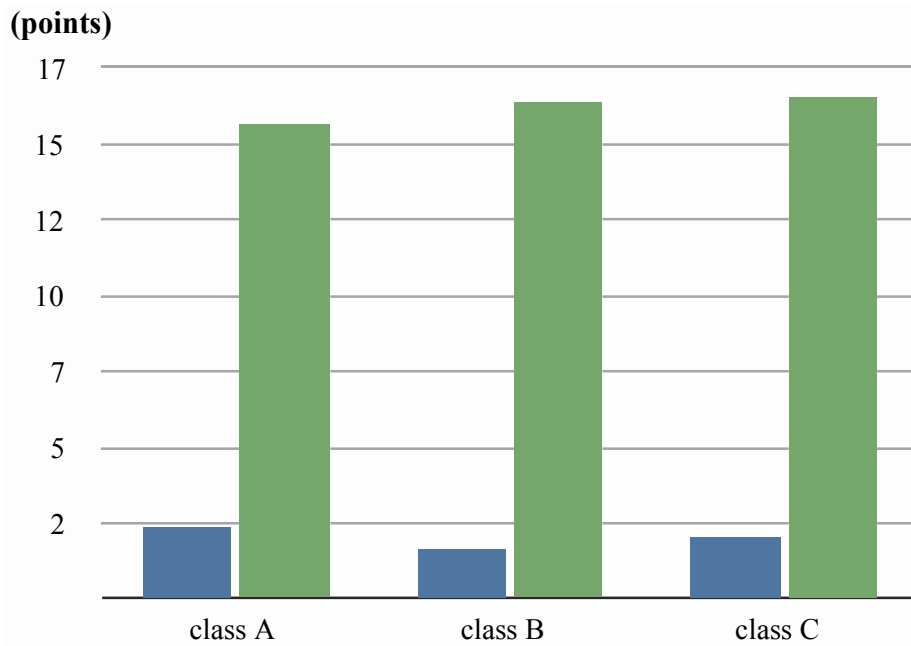
(points)

Figure 4: Results of students' conceptual change

Table 1: Results of evaluation of learning support functions by students

	TS	STS	DQTS	DTS
By drawing my line, I understood well which idea I thought was right.	87	22	4	0
By drawing my line, I could explain well which idea I thought was right.	57	43	11	2
By superimposing their lines on my line, I understood well which idea other students thought was right.	98	11	3	1
By superimposing their lines on my line, I understood well the difference between which idea I thought was right and which idea other students thought was right.	93	18	1	1
By superimposing other students' lines on my line, I re-examined my own thoughts about which idea was right.	56	40	11	6
By superimposing other students' lines on my line, I want them to ask questions or comment.	48	42	17	6
By superimposing their lines on my line, active discussions between other students and I began.	52	36	16	9

N=113 (one student absent). TS: Think so; STS: Somewhat think so; DQTS: Don't quite think so; DTS: Don't think so.

Evaluation of Learning Support Functions by Students

Table 1 shows selected question items about the expression and reference functions. Regarding the effectiveness of these functions for learning support, the positive evaluations outnumbered the negative for every item ($p < .01$). Many students acknowledged that the use

of expression function supported the reflection of their own conceptual ecologies, and the use of the reference function supported the mutual examination of students' conceptual ecologies in the group discussions.

CONCLUSIONS AND IMPLICATIONS

In this research, we developed a mobile computing system by digitising the fortune line method. In addition, we evaluated a possible effect in supporting science learning. Elementary students changed their naive concept to a scientific concept after learning in the science curricular unit implemented in the system. The students positively evaluated the system's learning support functions. These results lead us to the conclusion that the system possibly supports science learning oriented to conceptual change.

The most important results are that the system supports the visualisation and sharing of the commitment of numerous learners to multiple ideas. This is because providing this support is difficult in the paper-and-pencil method, but is realised by using mobile computing technology (Chan et al., 2006). It is expected that our research will contribute to the increasing popularity of mobile computing technology among the public with regard to the research and teaching practice of science education.

NOTES

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