

# Introducing Hypermedia Learning Resources in a Physics Course on Semiconductor Devices for Electronic Engineering Students

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**ABSTRACT:** *Quantum Mechanics' knowledge, Statistical Physics and their applications on Condensed Matter constitute the basis of the main concept that supports a Physics Course on Semiconductor Devices for Electronic engineering students. Discrete energy levels, stationary electronic states, absorption and emission of quantum energy, generation, recombination and diffusion of charge carriers, are some of the most important concepts in the course. Such concepts aren't easy enough for our students. The construction of the associated scientific frameworks requires high cognitive demands. The non intuitive character of the concepts involved in Quantum Mechanics is one of the main obstacles for the learning processes. In addition, since the entire Electronic Engineer program was changed, the curriculum has been altered. The reduction of time of the previous Physics Courses constituted new problems we had to face. While the traditional course content remained almost identical we had to incorporate the basis content of Quantum Mechanics.*

*In order to improve the learning processes the authors developed a hypermedia assisted self study system called "Del átomo al sólido". It was used as a teaching resource during three academic courses, performing three different research situations. In this paper we describe the hypermedia system and examine learning outcomes and students satisfaction.*

## 1 INTRODUCTION: QUANTUM MECHANICS AS A CURRICULAR PROBLEM

Physics IV as a subject, is studied in the second semester of the second year of Electronic Engineering. It deals with the specific contents of Materials Physics and electronic devices. Students' former education in the area of the Experimental Sciences includes basic courses on Mechanics, Optics, Thermodynamics, Waves, Electromagnetism and General Chemistry, within the context of classical paradigms.

Due to a reduction in the duration of the whole program of study, essential Quantum Mechanics' contents have been added to the program of this subject; however, there was not an increase of the curricular hours involved.

These contents are the first of six didactic units. Taking on the students' previous knowledge and the learning objectives, the lecturing of Quantum Mechanics poses from the very beginning the need of a transition to the quantum paradigm. The study of the so-called crucial experiences and the discussion of different atomic models are carried out taking into account its application in the structuring of the model of the atom, which proves to be explicative and adequate for the study of molecule formation and for Physics of the micro solid. This together with elements of Statistical Physics, different interactions and microscopic processes involved in the study of matter are analyzed, taking into account the different aggregation states. Following a scientific approach open in every case to application, enables working with hypothetical systems at the level of theoretical material structures which become increasingly complex, in and out of equilibrium. According to some design considerations, those hypothetical material structures turn into concrete technological products (Marchisio, S. and Von Pamel, O., 2000a).

From our point of view, the study of Quantum Mechanics shows different characteristics from the ones within the Classical Physics' framework. Some relevant differentiating aspects are the need of a

substantial change of paradigm and the fact that its object of study cannot be directly perceived by the senses. Beyond requiring a thorough understanding of the dynamics of scientific work in the search for knowledge, this also clearly confronts the student with the need to overcome cognitive difficulties to reach an adequate resignification of concepts, involving a change of perspective in the ways of thinking, analyzing and explaining phenomena involving a high demand of abstraction and learning time (Fischler and Lichtfeldt, 1992; Johnston, Crawford, and Fletcher, 1998; Cabanellas, Marchisio, Von Pamel, 1995)

Within this context, designing a multimedia system in hypertextual format was a strategy to solve the complex equation that involves the inclusion of Quantum Mechanics in the context of this subject: a great amount of contents, little lecturing time, high demand on learning time, high demand of abstraction and the objectives of the subject matter.

## **2 THE HYPERMEDIA SYSTEM AND THE LEARNING GOALS**

The problem of teaching and learning scientific-technological contents cannot be carried out today without the new information and communication technologies (NICT). However, we must overcome the idea that with NICT the same as before is taught, but in a more efficient way. It is widely known that these technologies allow for the development of systems to select information, manage, process, simulate, model, calculate, approach sources of information (all essential objectives in the learning of Sciences). We must not, however, believe that these resources are intrinsically effective and learning facilitators. From our perspective, in order to take advantage of the huge potentiality of these technologies, we need to change the pedagogical framework of our teaching activities, which involves general objectives, specific contents and methodologies (Marchisio, 2003).

Engineering is a profession that is essentially creative. Different kinds of knowledge come together in it as products of processes of investigation and innovation in science and technology, developing in search of solutions to complex problems. For this purpose, the engineer formulates and carries out projects integrating working teams. In this process he develops, innovates, manages technology, communicates and supports ideas, explores alternatives and procedures, operating with different variables to satisfy a specific need of the design. This implies taking decisions to arrive at the best solution to the problem.

From the cognitive point of view, taking into account the information processing theories (Gagné, E. 1985; Simon, H., 1984, Pozo, J. I. 1994, 1995; Rivi re, A., 1987), the process associated to the resolution of a problem facilitates not only the production of knowledge in action (Watts, 1994) but also the design and articulation of strategies to organise that action (S nchez et. al, 1997). As the activation of concepts and articulated procedures is put into action for the search of a solution, the establishment of new conceptual relations is favoured implying, at the same time, an organised process of application of results from experiences acquired in previous situations with transfer to a different context (Massa; 1996). Thus, the value added by this way of constructing knowledge is to favour the appearance of metacognitive processes that relate to desirable attitudes in an individual with independent thought.

We, thus, consider it important to foster the development of teaching strategies meant to help engineering students to solve complex problems with the aim of promoting the construction of meaningful learning (Ausubel, D. et al, 1989). From the point of view of teaching, this implies proposing the realisation of activities characterised by the systematic and permanent search of knowledge with an emphasis on the process of its generation by articulating concepts, procedures and attitudes (S nchez et al, 1997). To our knowledge, these learning processes are optimised when they are produced collaboratively, i.e., in a context of interpersonal interactions that may be either direct or mediated by the instruments or resources to which the student has access (Vygotsky; 1977).

Therefore, from the cognitive point of view and bearing in mind the teaching of Quantum Mechanics in Engineering courses, the hypermedia system ‘Del  tomo al s lido’ carried out in the subject Physics IV, was conceived in the framework of what Wertsch (1999) calls mediated action. This is closely linked to Vygotsky’s main category defined as ‘zone of proximal development’ and, together with it, to the concept of ‘scaffolding’, understood as a situation of educational interaction through which the intersubjective turns into the intrasubjective. All this aims at searching and acquiring complex knowledge when solving problems that imply contents relevant for a scientific-technological education, also based on hypothesis making, modelling, contrasting and designing. Taking into account the cognitive processes

involved in learning, we take for granted that students not only acquire knowledge but also build it using their experience and organized previous knowledge, which act for or against them when understanding, modelling and structuring the new knowledge.

### **3 THE HYPERMEDIA SYSTEM IN THE CONTEXT OF THE SUBJECT**

When designing and elaborating the hypermedia system we must not think that the potentialities or limitations which can be reached are only related to the media itself, but we must accept that this device interacts with a physical, technological, psychological, didactic, organizational and human context, which will influence the results achieved. The product obtained will not depend exclusively on its technological characteristics but on the levels of interaction established between the afore-mentioned dimensions and the media.

The experience of the authors in the design and application of computing resources for teaching purposes is broad (Von Pamel and Marchisio, 1996; Von Pamel et al., 2001; Marchisio et al., 2001a; Marchisio et al, 2003; Marchisio, 2001). Especially the employment of the simulation of Schrodinger's Equation (Von Pamel et. al., 2001), which was developed taking into account the structure of contents of the subject (conceptual hierarchy and sequencing), has shown the potentiality of this resource to help students establish cognitive bridges between basic Quantum Mechanics' concepts and those to come in the subject itself. Attending to this, it was interesting to promote the simulation resources developed in Visual Basic and the knowledge of author tools, integrating them into a hypermedia context, which would contribute, because of its structure, to a greater logic and psychological meaningfulness and, due to the multiplicity of representational means, to different but complementary visions.

Considering this and recognizing that students have different learning styles, the inclusion of the hypermedia was thought to be one further resource along with the use of written material, INTERNET resources (sites, e-mail, electronic lists), videos, laboratory practices and other individual and group activities in pencil (Marchisio and Von Pamel, 2000b; Marchisio et al, 2001b). The teacher assumes the role of task organizer, providing students with relevant problems and all the possible resources, coordinator and guide of the processes, and generator of learning situations (Marchisio et al, 2002).

Within this context the hypermedia learning resource had to:

- Be easy to integrate as a flexible resource in the curriculum, attending to the features of the disciplinary approach, didactic objectives and communicative strategies.
- Have a visual background which gathers in image format outlines of the different material structures, capable of being used in the study of electronic devices.
- Allow for educational interactivity and foster the access to exploration, manipulation of relations, hypothesizing, modelling and designing.

What with an intuitive control of the system from the technical point of view and the support of the above-stated facts, the following objectives were required from the hypermedia. It had to:

- Foster the creation of highly knowledge-related structures through information links.
- Integrate the Science-Technology-Society approach, understood as a multiplicity of 'voices.'
- Keep interest and motivation.
- Enable different courses and levels to deepen the study of phenomena.
- Promote collaboration during problem-solving activities.
- Integrate the tools to Internet and Office resources.

### **4 DEVELOPMENT OF THE WORK**

Considering the exposed aspects, the evolution of the atomic models since the Greeks until the Rutherford model were all developed in the first phase, all of them within the classical paradigm.

It was later continued with the evolution of the models since the Rutherford until the current hydrogen atom. That is to say, the quasi-classical and quantum models were encompassed and the necessary elements of Modern Physics were introduced to enable understanding and development of these models within the quantum paradigm. All that without losing sight of the fact that the work in the hypermedia educational form must allow a second year engineering student to understand the main concepts of Quantum Mechanics, to know the evolution of the atom models, to understand the current model of a monatomic atom, to be able to differentiate the classical from the quantum paradigm and to

favor the understanding of the phenomena and processes involved in more complex material structures. We believe that these aspects are basic for the proper understanding of electronic devices.

In the following diagram a sketch of the work carried out is given (Von Pamel, 2002).

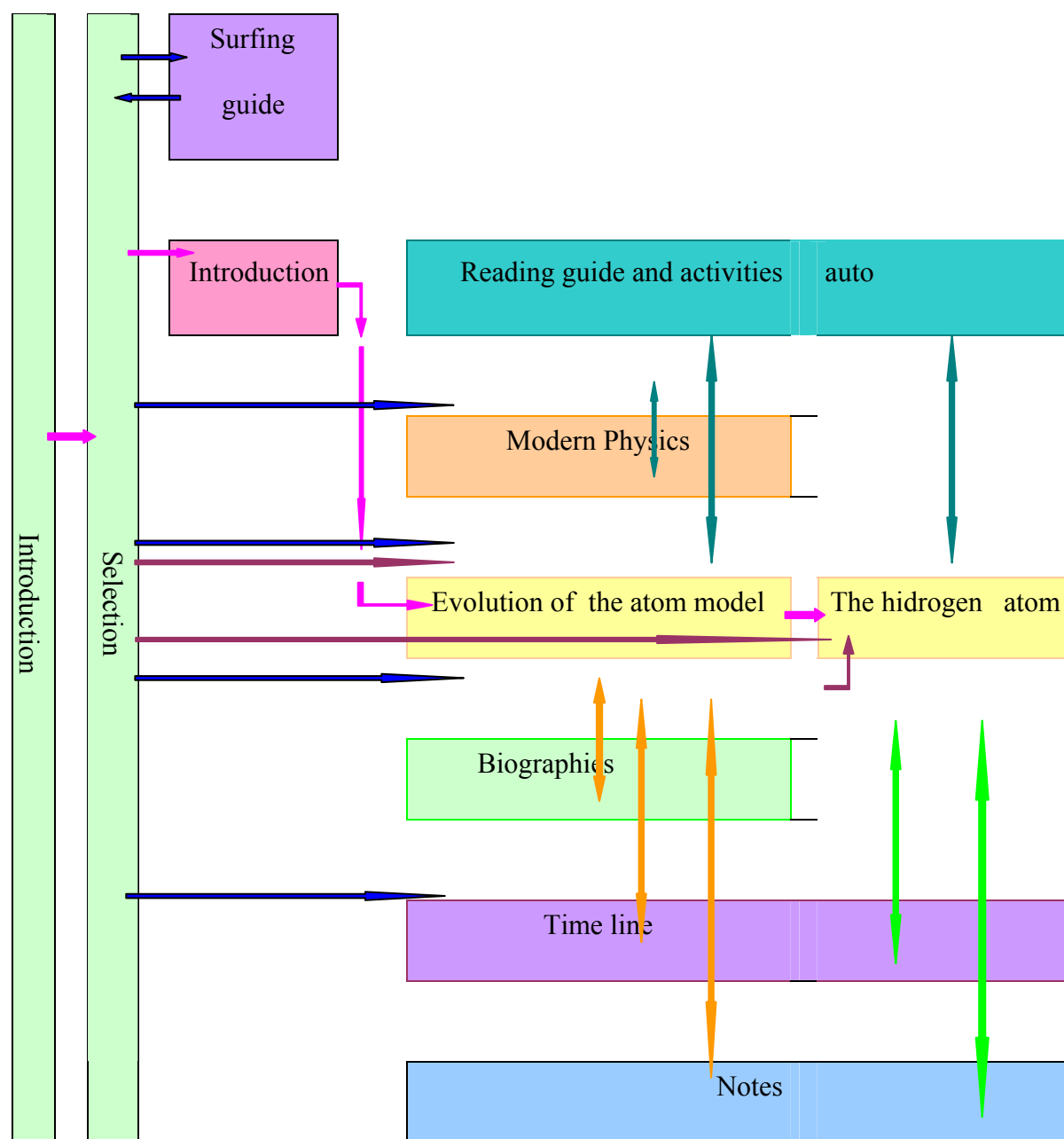


Figure 1 – Diagram of the main books of the hypermedia system

Possible entries to the books →  
Main entry →  
Entries to continue reading →

This system has been developed into software of author for hypermedia performances (Toolbook). It is compatible with Office and easy to approach by a teacher who is a non professional programmer (Ruffini, 2000). Integrated to the usual informative and communicative resources of a PC in Windows environment, from the superior panel of push buttons and with the opening of multiple screen levels, the system acquires the characteristics of a highly interactive platform. See Figure 2.

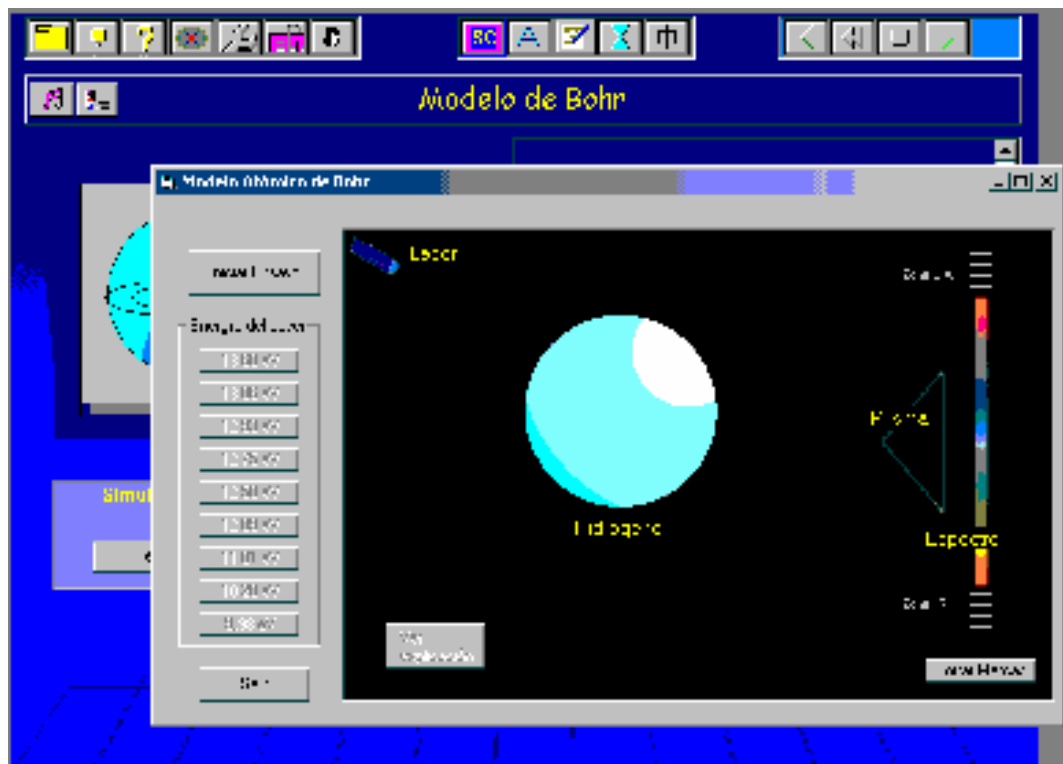


Figure 2 – Bohr's hydrogen atom model simulation and multiple screen levels

The hypermedia system combines:

- Video
- Fixed images
- Sound
- Text
- Animations
- Simulations
- It is integrated to the tools of communicating and PC processing tools
- It can be integrated into web systems (laboratories)

The procedural tasks were:

- Decision-taking in relation to the contents to be included in the hypermedia system paying attention to the required conceptual organization and the diversity of constructive variables involved.
- Script pre-production: Definition of a plot (order of events whether theoretical, textual, visual, and/ or sound)
- Performing of the general diagram of relations between the aspects related to: Content – Narration – Iconic – Sound – Technical

In all that the following were involved:

- Development of the classical, quasi-classical and quantum models in the book of models. Not all of them were set forth as explicit models of the atom themselves, since some are introduced as didactic resources (intermediate models) to achieve a better understanding of the evolution of the concept of the atom. In every case the new concepts introduced with each model and their errors or inconsistencies, which are to be corrected in the following model, are duly highlighted.
- Construction of an auxiliary book on Modern Physics to introduce the concepts the models require, which were produced in parallel form.
- Studying and carrying out the interrelation between the book on Modern Physics and the main book to continue with more complex material structures.
- Construction of the Biography book.
- Construction of the Time Line book.

- Construction of an Activity book of different levels of complexity, which may allow taking down notes and adding notes and commentaries in the same multimedia. Among these, integrative activities are highlighted as they are thought to constitute themselves into organizers of the work on the part of the student in the search for information for the solution of open problems.
- Incorporation of images, simulations and animations in the books.

Once the work was finished, we proceeded to:

- Revise the production in search of errors or bugs.
- Generate the physical support of distribution
- Design strategies for evaluation

## 5 EVALUATION OF THE HYPERMEDIA SYSTEM

What has been done in relation to the evaluation of the resource, highlighting methods, instruments and some results is synthesized below:

- Evaluation by experts: both a Physics researcher/ professor on Engineering, considered a specialist in contents of the Universidad Nacional de Rosario and a Thesis Board of Examiners of Mastery of Psychoinformatic Education of the Universidad Nacional de Lomas de Zamora, considered a specialist in the design of hypermedia systems (Von Pamel, 2002).
- Evaluation in context by students in use conditions. Specifically, a trial experience was carried out during the lecturing of the subject Physics IV, which was developed paying attention to three different experimental conditions during the years 2002 and 2003 (Marchisio et al., 2004).

In every case, students were given a CD containing the hypermedia system to be used under independent study conditions outside the university. However, as strategy of evaluation of the resource in use conditions, the same was also used with the presence of a professor in the context of the so-called theoretical classes. The basic element for the work in the classroom were activities understood as complex problems to be solved for learning and the procedural evaluation of knowledge as well as organizers of hypermedia reading in the search of solutions. This resolution task was integrated to the lecturing, according to the observed needs along the process, with others in harmonizing approach, using in some cases results of laboratory experience, expounding of ideas by the professor, and presentations by the students. The tasks included the strategies of association, manipulation, synthesis, integration, comparison, search of information, modelling, contrasting and design.

The subject was lectured in a parallel way, for contrast, integrating different activities, traditional study materials of the Department and the same structure of contents. It did not include the use of hypermedia resources. In both cases (traditional and experimental lecturing) to pass the subject, passing an oral instance lead by the team department independent of the lecturing is required.

The first experimental lecturing was developed with the participation of only 8 volunteer students in a multimedia resource classroom (video, laboratory, access to INTERNET) in which the distribution of the working tables does not provide a preferential place for the professor. The classroom is relatively small and there are 1 or 2 students per PC.

The second experimental lecturing involved 15 students selected at random in the same classroom, forming self-managed groups of 2 to 3 students, while the third implied 22 students who enrolled themselves freely. The classroom used in this case was the computer science laboratory of the university, which has a traditional space distribution of lined up tables facing a blackboard. In this case, star web connection was needed, counting on 11 PCs, 1 every 2 students.

The experimental design considered as variables:

- Number and form of work (individual/ group work) of students in an experimental lecturing that integrates the use of the hypermedia system.
- Personal motivation of each student in relation to the use of NICT as a learning resource in the context of the subject.
- The classroom's characteristics.

In this case, the evaluation of the experience that was made took into account the analysis of processes and results. The resources used to get information were:

- Opinion poll
- Interview to some students

- Observation of classes in the manner of participant observation
- The activities performed by the students conceived as the tangible products that can be evaluated and that reflect, to a large extent, the suitability of the experience in relation to the formative objectives.

As strategy of methodological triangulation we considered the crossing of data (numerical and non numerical) coming from different instruments.

Some of the issues related to the employed instruments that were researched were:

- Attitude towards the new technologies. Some of the instruments used in this case were: class observation, opinion poll and interview to some students.
- Student adaptation to the new way of reading. This aspect was researched through opinion polls and interviews.
- Possible distractors / surfing. This was carried out with polls, interviews and observation.
- The existence of obstacles hindering the understanding of associations. The activities carried out by the students of this group were analyzed, paying special attention to the achievement of the learning objectives of the subject and to the level of depth in the study of phenomena and processes developed by the students.
- Students' view of the study material, in particular what relates to the degree of integration between this and the other study materials and according to the contents dealt with in class. For this purpose, polls were carried out and activities performed by students were analyzed.
- Superficial structure of the work. Here opinion polls and direct class observations were carried out.
- Teacher and student roles. All instruments were used, being class observations and opinion polls the most relevant ones.

## 6 FINAL APPRECIATION AS A PRELIMINARY ANALYSIS OF THE RESULTS

The development of this investigation is still in process. However, some significative results have already been found:

- The appreciation that implied the didactic innovation of introducing this hypermedia resource in one of the subjects of the Engineering course conducted in a traditional university, to both students and the Department,
- Students' attitude towards the use of these technologies within a teaching context.
- How this new resource integrates and its potential as didactic material in the subject,
- Attention to the difficulties posed by the contents,
- Additional difficulties found by students and professors due to the new implementation.

From the student's perspective, it has been found that students clearly perceive a reshaping of the roles, both theirs and the professors'.

He assesses as positive:

- The innovation of introducing the hypermedia from what he perceives as the achievement of effective learning, the form of work, the integration of communicative and didactic resources and the style of lecturing in the context of the classroom.

In the same way, and related to the former, he highlights the importance of:

- Autonomy, shown in the sense of freedom when choosing resources and time, and in the use of different learning evaluation strategies.
- The atmosphere in the classroom.

Furthermore, it could be affirmed that the student assesses the integration of the media and the use of the Net (INTERNET sites, simulations, communication resources) as positive. Also, the student dears to make proposals to professors, cooperates and contributes; expresses himself on changes of attitudes / motivations and the ways of approaching the study, assumes more protagonism and responsibility.

In connection with the learning of the contents, it could be affirmed that the group of students that took part in the experimental course as well as the group of students who studied the subject without using the hypermedia, have reached the level of knowledge required to pass the subject. However, in the students' output certain differences have become evident in what respects to the types of argumentation exposed when solving a problem. As we see it, this is related to the possibility of widening the field of the

sensitive, in opposition to the abstract, due to the use of animation and simulation resources, which implies a change in the use of problem-solving strategies.

On the other hand students viewed as obstacles:

- Some specific aspects of the superficial structure of the design of the hypermedia
- The need to adopt a new way of reading / surfing
- Uncertainty because of the wide diversity of ways of access to the information and because of the need to change effective problem-solving strategies developed in other subjects. This is related to what has been analyzed regarding the evaluations, and, we believe, is associated with the use of a representational medium that allows for alternative problem-solving strategies, and not only mathematical calculations.
- Waste of time in operative matters, speed problems of the system in some cases, related to the specific features of the PCs students have at home.
- Dependency on the PC.

As for students' attitudes, they expressed their agreement on this methodology. It can be said that the motivation of the students was, at first, related to the incorporation of the technological resource and, later, to the satisfaction derived from realizing that the activity that they were carrying out was meaningfully contributing to their development.

Finally, here is a word on the characteristics of the context, where the activity develops. Although students have assessed the classroom atmosphere as positive, this is influenced by the way working tables are arranged, the possibility of being part of an experimental observation, the more or less flexibility of the chairs to carry out group activities and the size of the classroom, in relation to the number of students who are simultaneously working in groups. These conditions obviously affect the pedagogical process favoring or hindering the development of certain didactic strategies, at the same time conditioning the communicative processes involved.

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