SOCIOLOGICAL STUDIES OF THE CLASSROOM

# Students-Exhibits Interaction at a Science Center

## A sociological study of characteristics that affect learning

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# STUDENTS-EXHIBITS INTERATION AT A SCIENCE CENTER

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## Introduction

As new science museums are created and existing museums renovated, the exhibits are becoming increasingly interactive (Reid, 1997; Swift, 1997). To signal this change, many museums are now known as Science Centers. We assume that this change to more participative exhibits has implications for teaching and learning science. The attraction and involvement power of these exhibits has led to various studies to analyze their educational potential (e.g., Anderson & Lucas, 1997; Falk *et al.*, 1998; Feher, 1990; Henriksen, 1998; Serrel, 1997).

These studies showed that, during interaction with exhibits, specific characteristics influenced visitor behavior. Falk *et al.* (1985) identified three broad groups of characteristics that affect visitor behavior in a museum: visitor characteristics, setting or environmental characteristics, and exhibit characteristics. In this exploratory study, we intend to make these characteristics more specific and to do a more detailed analysis, by using Bernstein's theory of pedagogic discourse, as the theoretical framework.

## Literature review on students-exhibits interaction

Departing from earlier learning studies that showed that museums only occasionally facilitate learning, recent studies support the premise that learning takes place in museums (Falk & Dierking, 2000). Museums offer opportunities to interact with materials, objects and ideas, which may not otherwise be readily available to learners (Thier & Linn, 1976; Miles, 1987; Jackson & Hann, 1994; Russell, 1995).

The level of interaction with exhibits varies according to different variables. Several studies have focused on visitor characteristics and on the relation between these characteristics and learning evidences. Gender is one of the most studied characteristics. Some authors (Tulley & Lucas, 1990; Kubota & Olstad, 1991) found differences between boys and girls. Tulley and Lucas (1990) observed that boys revealed greater exploratory capacities and dexterity than girls during the interaction with the Lock and Key exhibit, in the Launch Pad of the Science Museum in London. Kubota and Oldstad (1991) studied the relation between novelty, exploratory behaviour and learning. They observed that previous activities that promote the reduction of novelty have distinct effects on boys and on girls – in the case of boys they promoted an exploratory behaviour and cognitive gains in relation to the scientific knowledge transmitted by the exhibition. This evidenced the role of gender in the exploratory trends of the exhibits.

Boisvert and Slez (1994) studied the relationship between gender and social group and three types of behaviour considered as important pre-requisites for learning in museums: 1) attraction (an exhibit's ability to grab a visitor's attention), 2) holding power (how long an exhibit holds visitors' attention), and 3) engagement (the level of interaction with the exhibit), in exhibits related to the human body. The results showed the absence of significant differences in the relation between each visitor's characteristic and the three types of behaviour. The authors justified these results with a common interest of both boys and girls by the human body. Another study that showed the unexistence of differences between boys and girls interest was carried out by Busque (1991). He analysed the interest raised by interactive exhibitions of the Ottawa Museum in visitors.

Despite the fact that research has been focused on various students' characteristics, no study has been done on the socio-economic status of the students' families or on students' school achievement. However, many studies on schools formal contexts (e.g., Morais & Neves, 2001) have shown the importance of sociological variables for students' scientific learning. Exhibits characteristics (attraction, holding power, and engagement) have also been studied and related to visitor characteristics (Boisvert & Slez, 1994).

Some other researchers point out to characteristics that evidence the exhibits success in arousing interest, allowing involvement, and transmitting the ideas entailed in them. Carlisle (1985) observed students visiting the Arts, Science and Technology Center (now Science World) in Vancouver, Canada, and recorded the exhibits students chose, the length of time spent at the exhibit and the level of involvement with the exhibit. Other researchers have used these parameters - choice, length of stay and level of involvement - as a measure of the success of exhibits (Cone & Kendall, 1978). Carlisle used these results, however, to gain insight into the learning behaviors of the students. She found that most students orientate themselves when they first arrive, involve in both solitary and social experiences, but with sharing and cooperative behaviors predominating, and most students made repeated visits to some exhibits. She concluded that the center as a learning environment provided a context that "motivated, encouraged meaningful behavior and social interaction, was pleasurable, and held the potential for learning scientific facts and principles" (Carlisle 1985: 32).

Other factors that could affect students-exhibits interaction are related to previous knowledge, the reading of labels and the exhibits' design. Symington and Boundy (1986) found that students may bring a great deal of relevant knowledge to a museum, but do not necessarily use it to direct attention, or change their understanding as a result of viewing the displays, and conclude that this is partly because the majority did not read the labels. Other authors (Falk, 1997; Gilbert & Stocklmayer, 2001) demonstrated the influence of the exhibits design on visitors' behaviors. Falk (1997) analysed the effect of two exhibitions, one with and another without explicit labelling and observed that, in the first case, visitors not only learned more about the specific information and general ideas but spent more time in exploring the exhibition. Gilbert and Stochlmayer (2001) included the idea of memory retrieval in their analysis about how the experience of the interaction with the exhibit elicit the remembrance of former experiences, which constitute an analogy to the construction of the present experience. These past experiences may include school experiences.

## Literature review on the learning context

What is learned is inseparable from how it is learned which means that students respond differently to an experience depending on the environment that they encounter (Morais *et al*., 2000, Botelho & Morais, 2003; 2004). They react differently to questions from a stranger or a peer, they respond differently to environments that allow free exploration compared to a tightly structured environment (Botelho, 2004). Other authors emphasize the idea that knowledge construction may be influenced and aided by contexts and that these contexts, afford rich links with the students' interests (Hein, 1991; Carr & Barker, 1994; Hein & Price, 1994). Fensham and Gunstone (1994:5) speak of the "reflexive and interactive relationship between knowledge and actions" (p.5) - one feeding on the other. Further, Lave and Wenger (1991) and other situated cognitive educationalists see the context as influencing not only what is learned but as being an inherent part of what is learned.

Driver and Asoko (1994) emphasize the importance of the context. They argue that learning science involves both personal and social processes, and suggest that if knowledge construction is seen as a purely individual process, this amounts to discovery learning. Rather, they see science learning as a process of enculturation, and describe a social constructivist view as one in which there is interplay between personal experience, language, and socialization in the process of learning science. Also contributing to a social constructivist view are the work of Lemke (1990), seeing learning science as learning to 'talk science', and Lave and others' ideas of cognitive apprenticeship and situated cognition (Rogoff & Lave, 1984; Lave & Wenger, 1991).

At the level of the museums, Falk and Dierking (2000) expand the importance of the context and postulate a "contextual model of learning" to describe learning in museums, summarizing much of the research findings in museum studies. The model includes three interlinked contexts: personal, socio-cultural and physical, with the intersection of these contexts describing the learning experience of visiting a museum. The personal context includes (1) motivation and expectations, (2) individual's prior knowledge, interests, and beliefs, (3) choice and control. The social context includes (4) within-group socio-cultural mediation and (5) facilitated mediation by others. The physical context includes (6) advance organizers and orientation, (7) design, and (8) reinforcing events and experiences outside the museum.

Despite the importance of the context in creating adequate learning contexts to students, Escot (1999) argues that to give students' opportunities to learn does not mean that students learn. We then shoud ask: what do students need to learn with success? We believe that part of the answer can be found in Bernstein's theory of pedagogic discourse (Bernstein, 1990; 2000). According to Bernstein, the characteristics of the pedagogic context are very important. However, to him, students must have rules, which allow them to recognize these characteristics, and rules, which allow them to produce the text, expected in this context.

## Theoretical Framework

Bernstein's theory of pedagogic discourse (Bernstein, 1990, 2000) provided the sociological concepts to characterize the interaction and to analyze the influence of specific sociological characteristics on students' scientific learning, in the pedagogic context of a science center. We use the expression "pedagogic context" as a context where relations of transmission, acquisition and evaluation of any form of knowledge take a place. (e.g., family, school, and museums, at diverse levels). Bernstein considers three main categories in any pedagogic context, subjects, spaces, and discourses.

Subjects are the persons (e.g., student, teacher, mother, friend, manager, designer, and curator), discourses are forms of knowledge specific of a context (e.g., academic and non-academic knowledges, various disciplines) and spaces are specific subjects' space (e.g., teacher's space and students' space).

In the specific pedagogic context of a science center, we can consider various relations between subjects (e.g., teacher-student, student-student, designers-student), spaces (e.g., various exhibits' spaces, Biology exhibits space and Physics exhibits space in a science museum), and discourses (e.g., students ideas-exhibits ideas).

Pedagogic contexts are regulated by power and control. Power refers to relations between categories and, consequently, it establishes categories positions while control refers to communication between categories.

Bernstein uses the sociological concept of classification to characterize power relations and the sociological concept of framing to characterize control relations in pedagogic contexts, whether in the school or in other sites. Classification (C) refers to the degree of maintenance between categories (subjects, spaces, and discourses) and expresses the power of a category over the others (power relations). It is weak when boundaries are blurred and strong when boundaries are well marked[1]. Framing (F) refers to the communicative outcomes of the relations between categories in the pedagogic relation and expresses the control of one category over the other (control relations). It is weak when lower categories have any form of control on the relation and strong when higher categories have the control on the relation[2]. Framing between subjects refers to the control they have over selection, sequence, pacing, and evaluation criteria[3], that is, the discursive rules that regulate the instructional pedagogic practice. It also refers to the hierarchical rules, which regulate the norms of social conduct, or the regulative pedagogic practice. Variations in classification and framing at various levels and in the coding orientation itself determine specific modalities of code. These modalities of code regulate specific pedagogic practices, either in the school or in other agencies (e.g. families, museums). Classification values of pedagogic practices create specific recognition rules whereby students recognize the specificity of a particular context. If classification values change from strong to weak, so do their contexts and recognition rules. Framing values shape the form of pedagogic communication and context management. Different framing values transmit different rules for the creation of texts, whether these texts are instructional or regulative. Figure 1 shows the relation between these concepts.

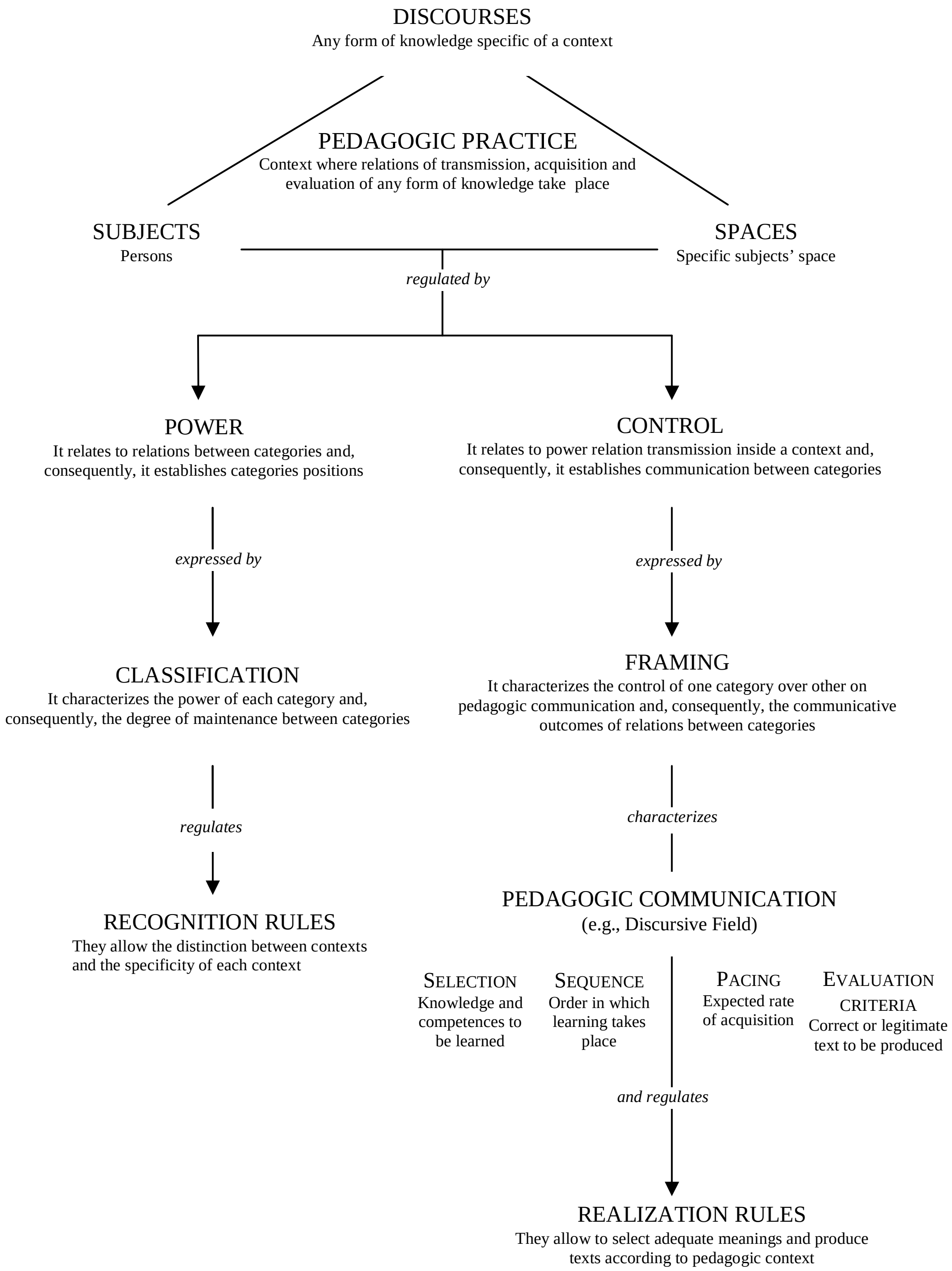



*Figure 1* - Pedagogic context dynamics (based on Bernstein, 2000).

To study the instructional and regulative texts produced by students in specific contexts of learning, we used a model (Figure 2) constructed by Morais and Neves (Morais & Neves, 2001) which shows the relations between specific coding orientation and socio-affective dispositions in text production. The interrelation showed in the model, between specific coding orientation and socio-affective dispositions, intends to highlight their mutual influence. Although constituting different realities within the subject, the possession of a specific coding orientation may be limited by socio-affective dispositions, which are in turn limited by coding orientation. According to Bernstein (1990), text production in a given context depends on the possession of the specific coding orientation to that context. This means that subjects must have both the recognition rules, that is, be able to recognize the context, and the realization rules, that is, be able to produce a text adequate to that context. Realization rules concern both the selection and the production of meanings. Subjects must select adequate meanings and produce texts according to them, in this way showing correct performance in context, demonstrating possession of both recognition and realization rules.

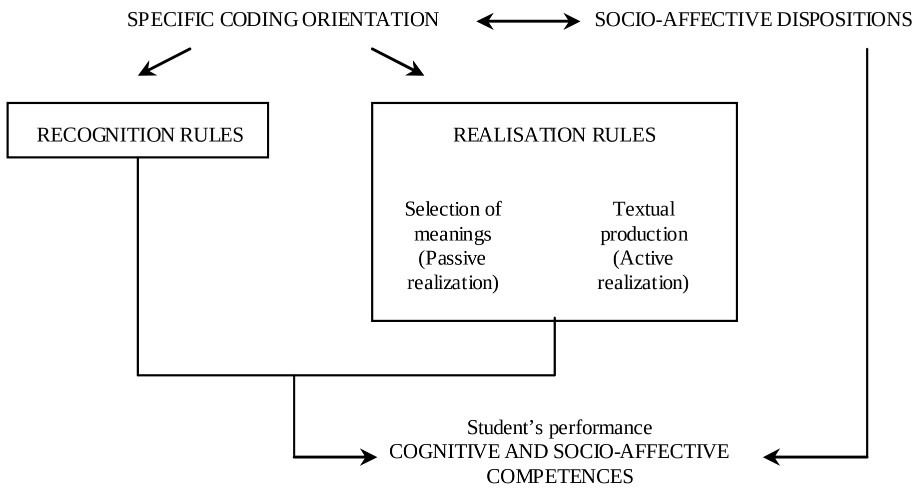



*Figure 2* - Cognitive and socio-affective competences as given by coding orientation and socio- affective dispositions specific to the context (Morais & Neves, 2001).

Failure to show performance may indicate lack of recognition or realization rules or both. Without realization rules, subjects may not be able to select meanings or produce them or both. If they are able to select meanings but are incapable of producing the text, we say that they have a passive realization. If the text is produced, they exhibit active realization. However, for text production to be accomplished subjects must also possess socio-affective dispositions specific to the context, that is, they must have the appropriate aspirations, motivations, and values. According to Bernstein, recognition rules regulate realization rules. Both rules and the requisite socio-affective dispositions are socially acquired and become part of the subjects' internal structures.

Exemplifying these relations among the cognitive competences required in specific learning contexts, we would say that students receiving a pedagogic practice which requires, for instance, problem solving competence succeed by (a) recognizing the specificity of the micro-context of problem solving within their practice (recognition rules); (b) selecting meanings adequate to that micro-context, that is, knowing how to proceed to solve problems correctly (passive realization); (c) producing the text, that is, presenting a correct solution to the problem (active realization); and (d) possessing socio-affective dispositions favorable to that realization (motivations, aspirations, values).

Bernstein's theory looks at both the macro level of the educational system and the micro level of the school and the classroom. However, the theoretical concepts he developed, and which constitute a powerful internal language of description, have allowed the development of an external language of description to study a multiplicity of contexts, from the school itself to the family and teacher training. What we have done in the present study was to extend it still further to the context of science centers.

## The Purpose of the Study

The study is part of the research that has been carried out by the ESSA Group[4] and used specific aspects of Bernstein's theory of pedagogic discourse to compare students' performance during their interaction with exhibits. The applicability of this theory in the analysis of the learning that takes place in science centers is, therefore, appreciated.

Within the context of students-exhibit interaction, we considered two micro-contexts of the interaction: students' procedures in exhibits and students' understanding of scientific concepts involved in exhibits. Concerning the micro-context of procedures, we analyzed the extent to which students could recognize the specific procedures of that context, more specifically if they could identify and characterize the exhibits with which they interacted, and if they could produce them correctly. Concerning the micro-context of concept understanding, we analyzed the knowledge students already had about the concepts involved in the exhibits and the extent to which they were able to acquire these concepts and in which degree.

The following question guided our research:

- How are characteristics of students, exhibits, and students-exhibits interaction influencing students' learning in the student-exhibit interaction, when this interaction is studied by using Bernstein' theory?

We analyzed the results in terms of students' specific coding orientation that is in terms of recognition and realization rules that students must possess for learning. If students possess recognition rules they can distinguish the various contexts and if they possess realization rules they can select (passive realization) and produce (active realization) the text specific to each micro-context. We also studied the relation between the results and the characteristics of (1) students (family socio-economic status, gender, and achievement), (2) exhibits (exhibits design, what happens when students activate the exhibit and evaluation criteria) and (3) interaction on students' learning.

## Methodology

This section contains the description of the students that participate in the study, the exhibits with which the students interacted, the visit to a science center, and a sociological description of the student-exhibit relationship. It also contains the description of the data collection and the analysis processes. We used qualitative methods for data gathering and a comprehensive-interpretative model for the analysis of results, because we wanted to understand the meaning of students' performance levels, as a result of the interaction with the exhibits.

### *Students*

The study is the result of a one-year educational research project and intended to be an exploratory study yet containing some degree of depth in the analysis of results. We selected eight students who represented all possible combinations of three variables with two variants each: gender, achievement and parents' education and occupation, as indicators of socio-economic status[5]. These students are not a random sample, but a carefully selected group of participants to represent pre-selected variables. They all came from the same school class of the seventh grade (ages $12^{-}$ - $13^{+}$). In order to determine the family's socio-economic status, we used a composite index of the academic qualifications and occupations of the mother (MAQ and MO, respectively) and the father (FAQ and FO, respectively), according to the formulae[6]

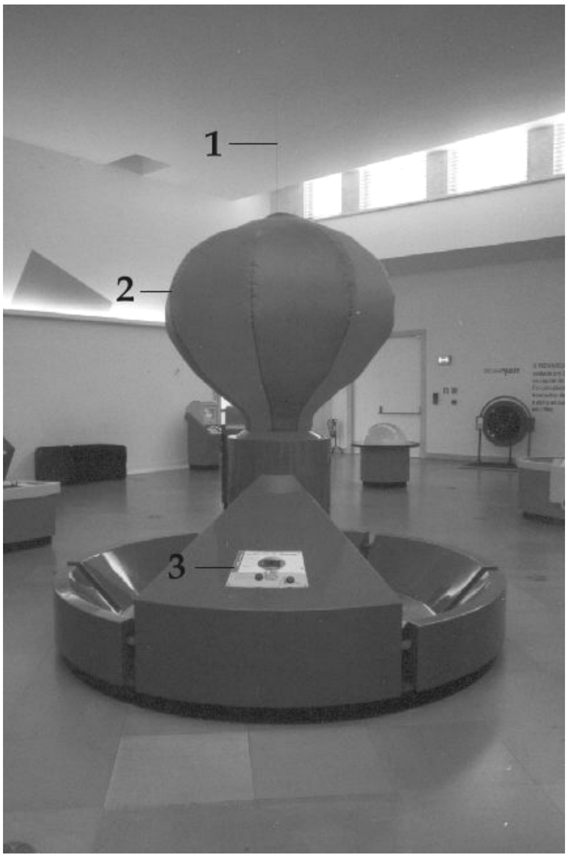
$$\frac{FO + FAQ + MO + MAQ}{24} \times 100.$$

Based on the data obtained, we constructed a two-degree scale in which I (17-50%) represents the lowest family's socio-economic status and II (51%-100%) the highest family's socio-economic status. Both groups of boys and girls contained an equal number of low/medium school achievers and high/very high school achievers. Figure 5 shows the distribution of students by gender, family's socio-economic status and school achievement. Students are named by pseudonyms.

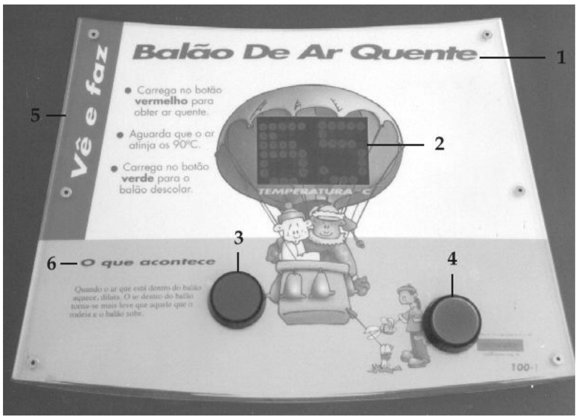
*The exhibits*

We developed the study in the Knowledge Science Center – Live Science, in Lisbon, Portugal. We selected two exhibits from the exhibitions present at the time the study took place – The Hot Air Balloon (figure 3) and the Hydrogen Rocket (figure 4) – which were part of the exhibition "Look, Do and Learn" conceived by Techniquest, the Cardiff Science Center. Both exhibits involved only two manipulating activities: press two buttons in the Hot Air Balloon and turn a handle and press a button in the Hydrogen Rocket. The former involved the Charles Law and the latter the constitution of the water molecule, the concept of combustion and the electrolysis of the water.

**A**




**B**

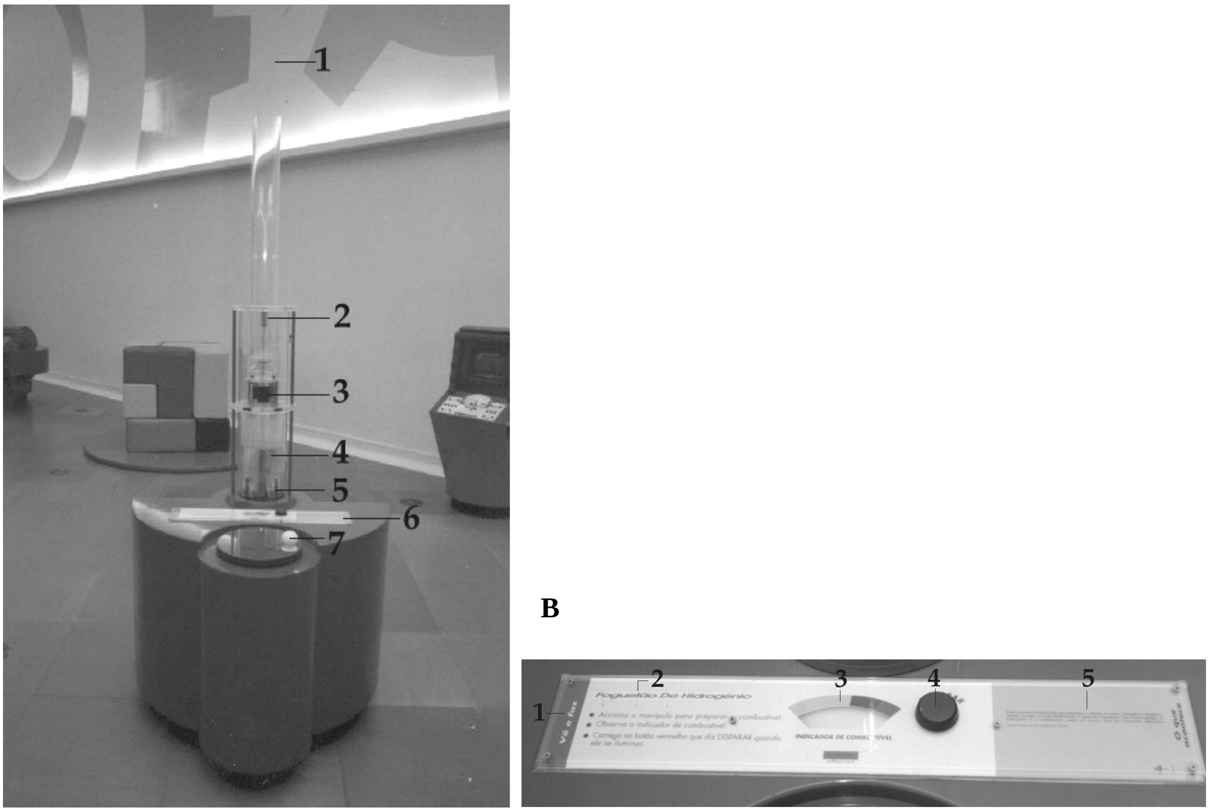



1- Name;
2- Count-up temperature;
3- Button to heat the air;
4- Button to release the balloon;
5- What to do;
6- What happens?

1 – Vertical wire;
2 - Balloon;
3 – Buttons and label.

*Figure 3* – Hot Air Balloon (A - General view; B – Panel 3 amplified)

**A**




1- Vertical wire;
2- Object (rocket);
3- Count-down sequence;
4- Water recipient;
5- Electrodes;
6- Label and buttons;
7- Handle

1- What to do;
2- Name;
3- Level of fuel;
4- Button to start the count-down sequence;
5- What happens?

*Figure 4* –Hydrogen Rocket (A – General View; B – Panel 6 amplified).

We based our selection on the information given by the science center curators. The two exhibits were the most visible and attractive in the exhibition so they were the most visited.

Intentionally, we used two exhibits with the same sociological characteristics, that is with the same values of classification and framing. This allowed us to concentrate on these characteristics. The analysis was centered only on the relations between the eight students and the two selected exhibits. However, it is important to stress that the exhibition as a whole showed a marked boundary between the various exhibits, that is each exhibit was isolated in the exhibition without any relation with other exhibits. This applied to both the message entailed in the various exhibits and the spaces they were allocated, although the former was particularly marked. The only criteria, which were used to display the exhibits in the exhibition rooms, were the aesthetic and the degree of attraction of the exhibits. This means that the exhibits were displayed throughout the room according to the perceptions of the team that organized the exhibition, and who was concerned with the distribution of the exhibits with lesser attraction power in strategic places of the exhibition room and the exhibits with greater attraction power in more discrete places. There was no concern for the establishing of any connection when any one visitor passed from one exhibit to another – each exhibit was important in itself. This means that, to the organizers of the exhibition, it was indifferent the way the visitor started and proceeded the visit. Looking at the whole exhibition one could not find any link between the various exhibits. The scientific areas, the themes, the facts and/or the concepts present in each exhibit had no pre-conceived inter-relations. Classification was, therefore, very strong between the various exhibits that constituted the exhibition.

STUDENTS-EXHIBITS INTERACTION AT THE LEVEL OF PROCEDURES

| STUDENTS' CHARACTERISTICS | | | | EXHIBIT TITLE | | | COMPONENTS | | | | | | | | | | RR | PROCEDURES | | | | | | | | PRL | ARL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | DESIGNATION | | | | | FUNCTION | | | | | | IDENTIFIES | | | | PERFORMS | | | | | |
| Ach. | FSEL | Name | Exhibit | N | I | C | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | | a) | b) | c) | d) | a) | b) | c) | d) | | |
| H | II | Sofia | Balloon | ● | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | III | - | ● | ● | ● | ● | ● | - | ● | II | II |
| | | | Rocket | ● | | | - | ✓ | ✓ | ✓ | - | - | - | ✓ | - | | I | - | ● | ● | ● | ● | ● | ● | ● | II | III |
| L | I | Raquel | Balloon | | ● | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | × | - | ✓ | II | - | ● | ● | ● | ● | ● | ● | ● | II | III |
| | | | Rocket | | ● | | ✓ | ✓ | - | ✓ | ✓ | ✓ | - | - | × | | II | - | ● | ● | ● | ● | ● | ● | ● | II | III |
| H | III | Sara | Balloon | | ● | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | III | - | ● | ● | ● | - | ● | - | ● | II | I |
| | | | Rocket | ● | | | - | ✓ | ✓ | ✓ | × | - | ✓ | ✓ | ✓ | | II | - | ● | ● | ● | - | ● | ● | ● | II | II |
| L | III | Sónia | Balloon | | ● | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | III | - | ● | ● | ● | ● | ● | ● | ● | II | III |
| | | | Rocket | ● | | | - | ✓ | ✓ | ✓ | - | - | ✓ | ✓ | ✓ | | II | - | ● | ● | ● | ● | ● | ● | ● | II | III |
| H | I | Miguel | Balloon | | ● | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | III | - | ● | ● | ● | ● | ● | ● | ● | II | III |
| | | | Rocket | | | ● | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | III | - | ● | ● | ● | ● | ● | ● | ● | II | III |
| L | I | Carlos | Balloon | ● | | | ✓ | ✓ | × | ✓ | ✓ | ✓ | | × | × | ✓ | II | - | ● | ● | ● | ● | ● | ● | ● | II | III |
| | | | Rocket | ● | | | ✓ | ✓ | ✓ | ✓ | - | ✓ | - | ✓ | × | | II | - | ● | ● | ● | - | ● | ● | ● | II | II |
| H | III | Nuno | Balloon | | ● | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | III | - | ● | ● | ● | - | ● | ● | ● | II | II |
| | | | Rocket | | | ● | - | ✓ | ✓ | ✓ | - | - | × | ✓ | × | | II | - | ● | ● | ● | ● | ● | ● | ● | II | III |
| L | III | Paulo | Balloon | | | ● | ✓ | ✓ | × | ✓ | ✓ | ✓ | | × | ✓ | ✓ | III | - | ● | ● | ● | ● | ● | ● | ● | II | III |
| | | | Rocket | | ● | | × | ✓ | ✓ | ✓ | ✓ | × | - | ✓ | - | | II | - | ● | ● | ● | ● | ● | ● | ● | II | III |

*Figure 5* – Results in the three levels considered in the interaction with exhibits at the level of procedures and respective degrees of recognition/ realization.

Notes

**EXHIBIT TITLE:**
**Balloon:** (N) Does not know; (I) Incomplete answer (e.g.: balloon); (C) Correct answer (e.g. Hot Air Balloon); (●) Selected answer.
**Hydrogen Rocket:** (N) Does not know; (I) Incomplete answer (e.g.: rocket); (C) Correct answer (e.g. Hydrogen rocket); (●) Selected answer.

**COMPONENTS:**
**Balloon:** (1) Balloon's going up vertical wire; (2) Balloon; (3) Count-up temperature; (4) Button to start the heating of the air; (5) Button to release the balloon; (✓) Answers correctly; (-) Does not know; (×) Answers incorrectly.
**Hydrogen Rocket**: (1) Count-down sequence; (2) Handle; (3) Button to start the count-down sequence; (4) Level of fuel; (5) Object (rocket); (✓) Answers correctly; (-) Does not know; (×) Answers incorrectly.

**PROCEDURES:**
**Balloon**: (a) Read instructions; (b) Press red button; (c) Wait until temperature reaches 90ºC; (d) Press green button; (●) Identifies/performs; (-) Does not identify/perform.
**Hydrogen Rocket:** (a) Read instructions; (b) Rotate white handle; (c) Look at the level of fuel; (d) Press red button; (●) Identifies/performs; (-) Does not identify/perform.

Ach – Achievement; FSEL – Family socioeconomic level; RR – Recognition; PRL – Passive realization; ARL – Active realization.; I, II, III – Degrees of the rules

*The trip to the science center*

The seventh grade teachers had programmed a visit to the science center in order to increase the interest for science, without having planned any specific tasks for students to do. Students could explore freely the place. The visit took one hour and half and involved the five classes of the school. Each one of the classes spent thirty minutes on the exhibition.

*The sociological student-exhibit relation*

Social interaction is usually seen as an interaction between persons. In the context of museums, this interaction occurs mainly between students, students and explainers, and family members. However, each exhibit present in a museum entails a sociological message. Messages transmitted by the exhibit may or may not be received by the students, depending on their specific coding orientation. When students interact with exhibits, they interact with "invisible subjects whose image is an exhibit". In this study, we look at students-exhibits relations as a social interaction between students and those subjects, and we analyze these relations.

Science centers have a pedagogic function although distinct from that of schools. Likewise the school context, the context of interactive exhibitions entails a pedagogic practice, determining a particular relationship between the subjects present, directly or indirectly, in that context. Distinct modalities of pedagogic code underlie distinct pedagogic practices, which are more or less favorable to the learning of socially differentiated students. A model based on Morais et al. (1993, 1996, 2001) orientated the characterization of the pedagogic practice, in sociological terms. According to the model, any pedagogic practice can be analyzed in terms of classification (C) and framing (F). We wanted to see if the same kind of analysis was productive when applied in the context of science centers.

We used a scale of values of classification and framing from very weak to very strong ($C^{--}$, $C^{-}$, $C^{+}$, $C^{++}$ and $F^{--}$, $F^{-}$, $F^{+}$, $F^{++}$) in which the signs (++) indicate relative degrees of very strong classification/framing and the signs (--) very weak classification/framing. The values (+) and (-) indicate intermediate degrees. We focused the characterization of the context on the relation of communication between the students and the subject(s) behind the exhibit, that is the constructors of the exhibits, as this was the crucial aspect of the study. It was possible to infer the sociological characteristics of the designers-students relation through the ‘features’ chosen by the designers to “be present in public” – the exhibit.

In spite of this communicational relation between the transmitter and the acquirer, this does not necessarily lead to a teaching/learning traditional perspective; rather the messages sent by the transmitter (facts or other kind of data) may act as a basis and orientation to the construction of concepts by students.

*Characterization of the micro context “Concept understanding”.* With respect to control relations, particularly in the case of selection, the students do not have any participation in the choice of the themes/contents, which are present in the exhibits – the responsibility of the selection lies totally with the team who planned the exhibits. Framing is therefore very strong ($F^{++}$). Students also cannot interfere in the sequence of the facts and concepts present, which is a consequence of the order chosen by designers. However, students have some control about mental appropriation and integration of the various contents. This means that a strong framing regulates sequence ($F^{+}$). Students controlled the time available for the understanding of concepts which means that a very weak framing ($F^{--}$) characterizes pacing. For both exhibits, it is not explicit for students what is expected from them to learn, that is framing of the evaluation criteria was very weak ($F^{--}$).

When we consider the power relations, it was the designers who determined, through the characteristics of the exhibits, the control students had on the relation between exhibit and students. This means that a strong classification ($C^{++}$) regulated the designers-students power relations.

*Characterization of the micro context ‘procedures’.* When we look at power relations between designers and students, we can see that are the designers who determine the relation student-exhibit. It is the designers who define the behavior students should have in relation to each one of the exhibits, through its general aspect, its characteristics and the sequence of the manipulating activities. This means that the designers-student power relations are regulated by a strong classification ($C^{++}$). In other words, the designers determine the legitimate relations between subjects, in the context of the student-exhibit interaction. These relations are also determined by the directors of the museum and by the principles that guide this kind of science museum.

With regard to control relations, we analyzed the discursive rules selection, sequence, pacing, and evaluation criteria. The student does not have any choice of the procedures, which are indicated in the exhibits, this meaning that the procedures, necessary to the correct functioning of the exhibits, are totally controlled by designers and therefore framing is very strong at this level ($F^{++}$).

We analyzed the sequence in terms of the tasks the student should do, when working with each one of the exhibits. In the case of the Hot Air Balloon, the designers of the exhibit previously established the sequence, which is written down on the information panel. However, the student has some control on that sequence because s/he can firstly press the red button instead of the green button. It is clear that such procedure will not lead to the expected result, but the student is free to do that, thus altering the pre-established sequence. Another aspect can also be changed by the student: instead of waiting for the air inside the balloon to reach 90ºC to press the green button (number 4, figure 3B), as indicated in the instructions, the student can press the button before the temperature reaches 90ºC and the balloon goes up nevertheless.

Something similar happens with the Hydrogen Rocket. The sequence of the tasks is also pre-established, but the student can change this sequence and instead of turning first the white handle (number 7, figure 4A), can press the red button (number 4, figure 4B). Similarly, to what happens with the Hot Air Balloon, this decision of the student will not lead to the expected result. In this exhibit, there is the possibility of changing another aspect of the sequence of the tasks. The student, instead of waiting for the red button to light up to press it, can do it before lightening. In this case, if there is already enough combustible, the rocket will go up when the red button is pressed, with no need to wait for the lightning sign, as indicated in the third stage of the instructions. In this way, the student changed the sequence of the tasks, although the control over this discursive rule is discrete, as this is not explicit to him/her. There is a strong framing ($F^{+}$), although not as strong as at the level of the selection of scientific content.

We considered that pacing was regulated by a very weak framing, because students have total control on the time they have to use and interact with exhibits. The trip had a closing time but students could spend the total trip time with an exhibit or two according to their own interests. Evaluation criteria were explicit in both exhibits as it was clear to students what is expected that they produce and what to do to achieve that production. It is quite explicit, in both exhibits, what one should do to obtain a given result: to make the balloon and the rocket going up. A very strong framing therefore regulates this discursive rule ($F^{++}$).

Table 1 shows the characteristics of the two micro contexts concerning power and control relations.

Table 1

*Sociological characteristics of the micro-contexts 'Concept understanding' and 'Procedures'.*

| EXHIBITS | MICRO-CONTEXTS | EXHIBIT-STUDENT RELATIONS | | | | |
|---|---|---|---|---|---|---|
| | | POWER RELATIONS (C) | CONTROL RELATIONS (F) | | | |
| | | | DISCURSIVE RULES | | | |
| | | | SELECTION | SEQUENCE | PACING | EVALUATION CRITERIA |
| HOT AIR BALLOON | Concept understanding | $C^{++}$ | $F^{++}$ | $F^{+}$ | $F^{--}$ | $F^{--}$ |
| | Procedures | $C^{++}$ | $F^{++}$ | $F^{+}$ | $F^{--}$ | $F^{++}$ |
| HYDROGEN ROCKECT | Concept understanding | $C^{++}$ | $F^{++}$ | $F^{+}$ | $F^{--}$ | $F^{--}$ |
| | Procedures | $C^{++}$ | $F^{++}$ | $F^{+}$ | $F^{--}$ | $F^{++}$ |

*Data collection and analysis*

We collected the data using three types of instruments: questionnaires, face-to-face interviews and video recordings. We used these three distinct instruments to collect all data needed, to reduce bias, and to triangulate the results. These instruments and their application are described as follows.

*Questionnaires.* We used various questionnaires. First, we constructed a questionnaire to gather data about personal and family characteristics: name of the student, age, gender, achievement's level in science, parents' qualifications and occupations, number of times s/he has visited museums, when and where.

The students of the five school classes (120 students) of the seventh year of schooling answered the questionnaire, in the science classes, three months before the visit to the science center. We then selected eight students, all from the same school class, who possessed the characteristics needed for the study.

Second, we constructed a questionnaire to study answers that students would give to the following questions:

1. What is a combustible?
2. Give four examples of materials that are combustibles and four of materials that are not combustibles.
3. What are the elements that constitute the water? How can you separate these elements? Explain the process.
4. How does the balloon go up? How does the balloon go down? (The questionnaire presented a balloon photo but the hot air mechanism was hidden).

In order to construct the categories of answers and to classify each one of them, in terms of its sociological meaning, the four classes, which did not contain the eight students of the study, answered the questionnaire, two months before. We identified four distinct students' conceptions: common sense, wrong, incomplete and correct. These categories are used when we analysed the results obtained in the students-exhibits interaction at the level of concept understanding.

. We classified each category according to its sociological meaning. Table 2 presents these meanings. Afonso (1995) used this method with success.

Table 2
*Correspondence between students' answers and the possession of recognition and realization rules*

| ANSWERS | RECOGNITION RULES | PASSIVE REALIZATION RULES | ACTIVE REALIZATION RULES |
|---|---|---|---|
| CS option | - | | |
| Wr option | - / + | - | |
| I option | + | - | - |
| C option | + | + | |
| Correct justification | + | + | + |

Note. (+) – Possession of the rule; (-) – Absence of the rule; If students select a common sense (CS) option, this means that, they do not possess recognition rules because they can not identify the context. If they select a wrong option (Wr), they can nor identify the context or know what text have to produce or they may recognize the context but do not know what the text they have to produce. This situation could occur if the students select an incomplete option (I) that is, students recognize the context and select incorrectly the text that they have to produce. If students select a correct option (C), this means that they recognize the context and they selected the correct text (passive realization rules). The possession of active realization rules is given by the correct justification.

Third, we constructed a questionnaire with multiple-choice questions to gather data about knowledge of the scientific concepts related to the exhibits. Students who participated in the visit to the museum answered this questionnaire twice, the first time, in the school, two days before the visit to the museum and the second time, in a room of the science center, immediately after the visit. This allowed us to compare students' knowledge before and after the visit.

With regard to the hot air balloon, and in order to facilitate the analysis, we considered two stages: the going up of the balloon and the going down of the balloon. Four questions made up the questionnaire, two respecting to the phenomena of the going up of the balloon and two respecting to the going down of the balloon. In both cases, the first question was a multiple-choice question with four options and the second question was a justification of the option chosen:

Think of a balloon to take people up, like the one in the figure.

1.1. From the options that follow, indicate the one that explains why the balloon goes up:
- The balloon goes up because it is pushed by the wind
- The balloon goes up because has a working engine
- The balloon goes up because there is hot air inside
- The balloon goes up because the air inside is hotter than the air outside

1.2. Justify the option selected.

2.1 From the options that follow, indicate the one that explains why the balloon goes down:
- The balloon goes down because it lost air from the inside.
- The balloon goes down because the engine stopped working.
- The balloon goes down because is full of cold air.

- The balloon goes down because the air inside cools down.

2.2. Justify the option selected.

The options of the first question allowed the analysis of the nature of the scientific concepts possessed by the students and also the understanding of the sociological meaning, in terms of recognition and passive realization (according to table 2). In fact, to answer the questionnaire correctly, students should recognize the context, that is they should have recognition rules and should select the adequate text, that is they should have passive realization rules. The second question, which asked the students to produce a text, would give information about active realization.

We obtained the level of SCO by adding the specific coding orientation for each part (the going up of the balloon and the going down of the balloon). We considered two degrees for each one of the rules. When a student had recognition rules (or realization rules) in only one of the two parts, we accorded him/her degree I and when s/he had recognition rules (or realization rules) in the two parts we accorded him/her degree II. There was therefore a two-point scale.

With regard to the hydrogen rocket, we questioned the students about the constitution of the water molecule (a multiple-choice question with four options). With regard to the concept of electrolysis, we questioned them about ways of separating water elements (the first question was a multiple-choice question with four options and the second question was a justification of the option taken). In the justification, students should explain how the selected process would separate the elements. With respect to the definition of combustible, we firstly asked students to choose among four options. We also asked them for a justification why these materials were combustibles. The questions are the following:

1.1. From the options that follow, mark the one that is correct:
- Only the petrol is a combustible
- Both hydrogen and petrol are combustibles
- Both water and carbon are combustibles
- Only the hydrogen is a combustible

1.2. Explain why is it that that substance is a combustible.

2.1. From the options that follow, mark the one that better indicates the elements that are part of the water:
- Hydrogen
- Hydrogen and oxygen
- Carbon and helium
- Oxygen

3.1. From the options that follow, mark the one that better indicates the process used to separate the elements that are part of the water:
- Letting water boil
- Heating the water
- Transporting electric current into the water

- Transporting electric current into and out the water

3.2. Explain why the elements that constitute the water can be separated through this process.

As we said above about the hot air balloon, the options allowed the analysis of the nature of the concepts possessed by the students and the understanding of their sociological meaning (according to table 2). We gave a point to each situation (the constitution of the water molecule, the water electrolysis and the concept of combustible) to which the student showed to possess a given rule. Three would be the maximum of points.

To study the relation, between the results at the level of concept understanding (Botelho & Morais, 2004) and at the level of procedures (Botelho & Morais, 2003), we determined the degree of specific coding orientation (SCO) by using the formulae $SCO = \frac{RR + RL}{Total} \times 100$, where recognition rules (RR) is given by the total number of points obtained in the situations which intend to test the possession of recognition rules and realization rules (RL) is given by the total of points relative to realization rules. The total of possible points is 38 to the performance at the level of procedures and 15 to the performance at the level of concept understanding. We converted the number of points achieved by each student to a four-degree scale[7]: 1-25: degree I; 26-50: degree II; 51-75: degree III; 76-100: degree IV.

Fourth, we constructed a questionnaire to gather data about students' behaviors during the interaction with exhibits. After the visit to the exhibition, we expected that the students could identify and characterize some of the exhibits present in it and we expected that they could recognize some of the elements of that context. According to this study's perspective, we took this procedure as an indicator of recognition rules. If the students were able to identify and characterize the exhibits, they possessed recognition rules. If they were unable to do that, they did not possess these rules. Three questions related to the hot balloon and three related to the hydrogen rocket made up the questionnaire. The questions were the same for both exhibits:

What is the name of the exhibit?

Identify the numbered parts on the exhibit picture. What is the function of each one of these parts?

When students had answered the questions, we gave them a photo of the exhibit.

In order to determine the degree of recognition and realization possessed by each one of the students we used a numerical scale. In the case of the name of the exhibit, there was a 0-2 points scale: (0) does not answer; (1) incomplete answer (e.g., Balloon); (2) correct answer (e.g., Hot Air

Balloon). With respect to the exhibits components, we gave one point to each correct designation or function. Thus, there was a 0-5 scale for the designations and a 0-4 points scale for the functions. These three aspects gave information about the possession of recognition rules and we constructed a 0-3 points scale[8] to indicate the degree of recognition: 0 – does not recognize; [1 – 4] – Degree I; [5 – 8] – Degree II; [9 – 11] – Degree III.

We associated the identification of the procedures with passive realization and used a four-degree scale: 0 – does not realize; [1–2] - Degree I; 3 - Degree II; 4 - Degree III to indicate the degree of passive realization. We followed the same procedure for students' performance. Doing the required procedures means the possession of active realization and a 0-3 points' scale indicates the degree of active realization: 0 – does not realize; [1–2] - Degree I; 3 - Degree II; 4 - Degree III.

Fifth, we constructed a questionnaire to gather data about students' socio-affective dispositions related to the exhibits interaction. The questionnaire was the same for both exhibits and was made up of three questions. The questions included opinions about exhibits looking/design, time spent with the interaction and students' feelings during interaction:

1. I think the exhibit was:
   - 1.1. (a)very pretty; (b) pretty; (c) normal; (d) ugly; (e) very ugly
   - 1.2. (a)very funny; (b) funny; (c) normal; (d) not funny; (e) not at all funny
2. From the moment I started working with the exhibit until it went up, I think it took
   (a) too much time; (b) much time; (c) enough time; (d) little time; (e) much little time
3. During the time that you interacted with the exhibit, you
   (a) enjoyed yourself; (b) had fun yourself; (c) played; (d) learned new things; (e) felt it was useless; (f) felt it was annoying; (g) understood what was happening; (h) felt it was very complicated
   (indicate yes or no; you may signal more than one sentence)

*Face to face interviews.* To assess students' knowledge of the scientific concepts present in the exhibits, we used the questionnaire above-mentioned and face-to-face interviews. We used these interviews to get a better understanding of the answers given to the entry and the exit questionnaires. Both interviews took place in a school classroom, respectively one day after the entry questionnaire and one day after the visit to the science center.

We also gathered data about students' behavior during the interaction with exhibits by using interviews. Both the entry and the exit interview focused on the following issues: exhibit aim; things (facts/concepts) that the exhibit demonstrated; procedures necessary to the balloon and the rocket going up; how these procedures cause the balloon and the rocket going up.

*Video records.* One of the behaviors expected from students, when visiting the exhibition, was that they made correctly the procedures necessary to the correct functioning of the exhibits.

However, in order to do that, students should have had access to the correct instructions. In the case of the two exhibits under study, the students should have read the instructions or watched other classmates doing these procedures. If the student could identify the procedures, s/he would possess passive realization rules that is s/he identifies the expected correct behaviors, independently of those behaviors being or not being performed. If the student could not identify the procedures, s/he would not possess these rules. If the students performed correctly the sequence of tasks necessary for the functioning of the exhibit, this would mean that they possessed active realization rules. If the students did not have a correct performance, they would not have these rules.

In order to obtain an answer to this, we observed students' behavior during the visit to the science museum and we analyzed the level of interaction (degree of active realization) with the two exhibits. To do this, we used a scale with the various possible expected behaviors, where the classificatory principle was correct-incorrect behavior. We gathered the data through video recording during 30 minutes. We placed four video cameras in strategic places in the science center. At all stages of the collection and analysis of the data, we followed ethical principles and legal constraints. We informed the parents, students and the school about all objectives and procedures of the research project and we obtained the consent of all of them. We guaranteed the confidentiality of the data and the family rights and privacy.

## Results

We separated the results in two sections. The first section presents the results of the students-exhibits interactions at the level of the procedures and at the level of concept understanding. The second section presents the results of the relation between students' procedures and concept understanding.

### *Students-exhibits interaction at the level of procedures*

In this section, we present the results for the balloon and for the rocket, comparing them before and after the interaction. After that, we compare the two exhibits. Figure 5 shows the results obtained and respective degree of recognition and realization.

*The hot air balloon.* The results show that most students were unable to indicate the name of the exhibit correctly, saying only that it was a balloon; only Paulo identified the exhibit as the Hot Air Balloon. Most students easily indicate the five parts, which constitute the exhibit; only Carlos and Paulo gave an incorrect answer to part number three. Similarly, most students were able to identify the function of each one of the four parts. From a sociological point of view, this means that the group showed, in general, to possess recognition rules at a high level (degree III).

With regard to procedures identification, there was a general absence of identification of the part of the procedures concerning the reading of the instructions. Students easily identified the other three procedures. The information about passive realization given at this level of analysis showed that students had an intermediate degree of realization rules (degree II).

Although, after the interaction with the balloon, most students could identify correctly the expected procedures with the exception of the reading of the instructions, we observed that, during the interaction, they followed the procedures they had identified and read of instructions. Considering that this level of analysis gives information about the active component of realization, we can see that the active realization attained, in general, intermediate to high levels. It is important to note that the students with low achievement (Raquel, Sónia, Carlos and Paulo) attained high levels of active realization.

When we look at the family socio-economic status of the students, low and high, and to students' achievement, low and high, the results indicate that, both students from low family socio-economic status and with low achievement simultaneously (Raquel and Carlos) showed to possess recognition rules at a level lower than other students did. We found no differences in passive realization rules but with respect to active realization rules, students with a low socio-economic status and low achievement showed values higher than students with a high socio-economic status origin and high achievement (Sara and Nuno). Considering the relation between the gender of the students and the possession of recognition and passive realization rules, we did not find any difference between girls and boys. That difference was limited to active realization rules, where boys, in general, showed better results.

*The Hydrogen Rocket.* The results concerning the identification of the name of the exhibit show that only two students (Miguel and Nuno) identified it correctly. Two students gave an incomplete answer (Raquel and Paulo) and four answered incorrectly. When naming the parts of the exhibit, only Miguel identified all of them correctly. Other students were either unable to identify one or more names or gave the wrong answer to one of the exhibit's parts. The exhibit's parts, which showed to be more difficult to identify, were the "count down sequence" (number 3, figure 4A) and the "object used to simulate the rocket" (number 2, figure 4A). It is interesting to see that only three students (Raquel, Miguel and Paulo) could associate the object with a rocket.

Miguel again only made the identification of the function of all parts of the exhibit. Other students showed difficulty in identifying the function of the various parts. This difficulty was particularly evident in the case of components 1, 2 and 4. In general, the whole group had an intermediate degree of recognition (degree II).

With the exception of the reading of instructions, students easily identified the procedures. None of the students achieved the highest degree of passive realization, degree II being the level achieved by the whole group. During the interaction, all students performed easily the expected procedures, with the exception of Sara and Carlos who did not read the instructions. This means that only Sara and Carlos showed to possess an intermediate degree of active realization (degree II), whereas other students achieved a high degree (degree III).

We found no differences between students in terms of their socio-economic status, gender and achievement.

*The two exhibits.* The graphs of figure 6 show the degree of recognition and realization for the two exhibits.

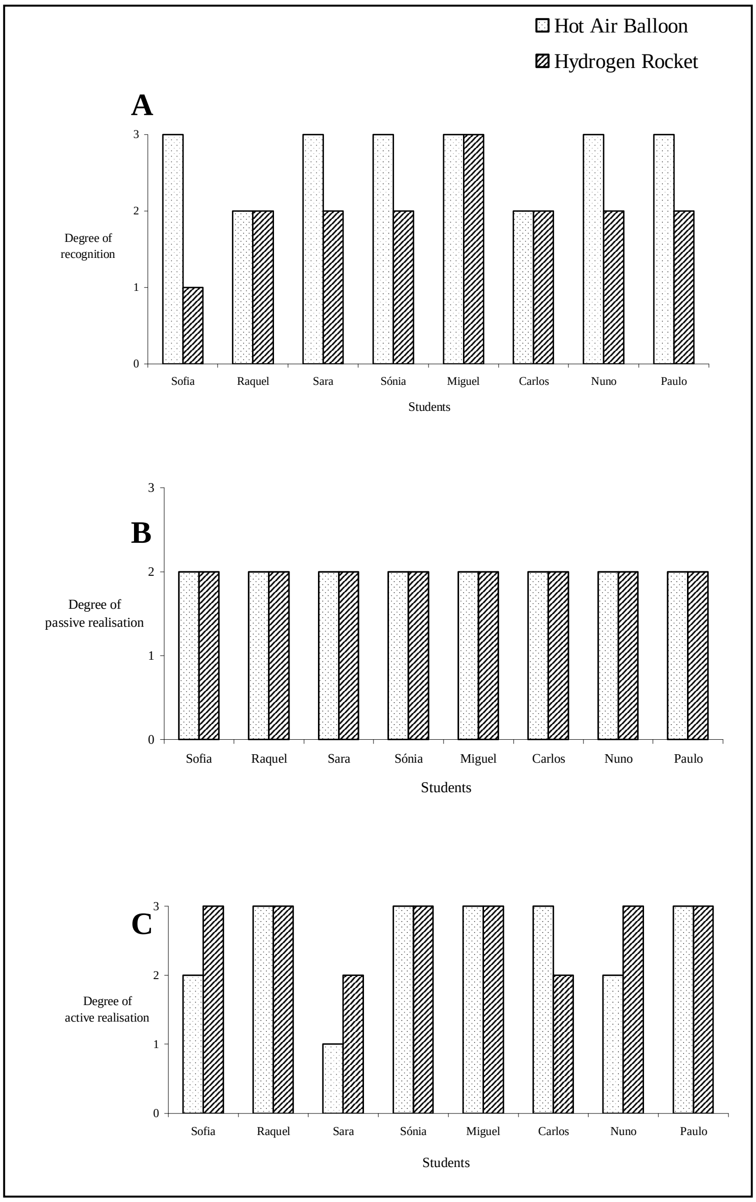



*Figure 6* – Comparison of degree of recognition, passive realization and active realization for the Hot Air Balloon and the Hydrogen Rocket.

The analysis of the three graphs shows that, in general, the students possessed an intermediate to a high level of recognition rules in both cases, the Hot Air Balloon and the Hydrogen Rocket. There were no differences between the two exhibits concerning passive realization. Active realization is, in general, slightly higher in the case of the rocket than in the case of the balloon.

The answers to the questionnaire to appreciate students' socio-affective dispositions[9] showed varied results, but some interesting points came out. Socially advantaged students thought the exhibits were annoying; they did not enjoy themselves, and thought everything was very complicated. On the contrary, socially disadvantaged students said the exhibits were funny, enjoyed themselves, and did not find it too complicated. With regard to students' understanding of what happened during interaction with exhibits, the majority of them said they had understood what happened with the balloon but not with the rocket. Most students considered that they had spent too much time with the balloon but the time was enough in the case of the rocket.

*Students-exhibits interaction at the level of concept understanding*

At the level of concept understanding, we analyzed the knowledge students possessed about the concepts involved in the exhibits, before the visit, and if they had acquired these concepts after the visit and also their degree of acquisition.

*The Hot Air Balloon.* Figure 7 shows the results obtained in terms of the categories of answers chosen by students (common sense, wrong, incomplete and correct), respective justification (wrong or correct), and the sociological meaning in terms of specific coding orientation.

HOT AIR BALLOON – STUDENT'S CONCEPTIONS AND SCO

| STUDENTS | BALLOON'S GOING UP | | | | | | BALLOON'S GOING DOWN | | | | | | SCO | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CATEGORIES | | | | JUST. | | CATEGORIES | | | | JUST. | | RR | | PRL | | ARL | |
| | CS | W | I | C | Wr | Cr | CS | W | I | C | Wr | Cr | B | A | B | A | B | A |
| Sofia | | | | ● × | ● → | × | | | | ● × | ● → | × | II | II | II | II | – | II |
| Raquel | | | | ● × | ● × | | ● × | | | | ● × | | I | I | I | I | – | – |
| Sara | | | | ● × | ● → | × | | | | ● × | ● × | | II | II | II | II | – | I |
| Sónia | | | ● → | × | ● × | | ● → | → | → | × | ● × | | I | II | – | II | – | – |
| Miguel | | | | ● × | ● → | × | | | | ● × | ● → | × | II | II | II | II | – | II |
| Carlos | | ● × | | | ● × | | ● × | | | | ● × | | – | – | – | – | – | – |
| Nuno | | | ● → | × | ● → | × | ● → | → | × | | ● × | | I | I | – | I | – | I |
| Paulo | | | ● → | × | ● × | | | | | ● × | ● × | | II | II | I | II | – | – |

*Figure 7* – Student's conceptions concerning the phenomena of the going up and going down of the balloon and their sociological meaning in terms of SCO.

Notes

**Conceptions when explaining the going up of the balloon:**

CS - The balloon goes up because it is pushed by the wind.
W - The balloon goes up because has a working engine.
I - The balloon goes up because there is hot air inside.
C - The balloon goes up because the air inside is hotter than the air outside.

**Conceptions when explaining the going down of the balloon**

CS - The balloon goes down because lost air from the inside.
W - The balloon goes down because the engine stopped working.
I - The balloon goes down because is full of cold air.
C - The balloon goes down because the air inside cools down.

**Conceptions:** CS – Common sense; W – Wrong; I – Incomplete; C – Correct; **Justification:** Wr - Wrong; Cr - Correct; **(SCO) Specific coding orientation:** RR – Recognition rules; PRL – Passive realization rules; ARL – Active realization rules; **Symbols**: **(●)** - Before the interaction; **(×)** – After the interaction; **(→)** – Direction of evolution.

Concerning the balloon's going up, the analysis of students' conceptions shows that before the visit to the science museum, students chose options, which involve conceptions of a school character, that is, wrong, incomplete and correct. Girls and high achievement students (Sofia, Sara and Miguel) predominantly chose the options which involve correct knowledge. When we look at the justifications given by students, we can see that no student gave a correct justification, that is they did not know why the fact that the air inside was hotter than the outside air made the balloon going up. These results suggest that, before the visit, students showed more difficulties at the level of realization than at the level of recognition.

After the interaction with exhibits, only three students (Sónia, Nuno and Paulo) changed their concept option from incomplete to correct and four students (Sofia, Sara, Miguel and Nuno) gave a correct justification to their option. These four students were those with high achievement and they showed to have a high degree of recognition and realization. These were even the only students, who had active realization after the visit.

Concerning the balloon's going down, the results showed that, before the interaction, four students gave common sense answers (Raquel, Sónia, Carlos and Nuno) and the other four (Sofia, Sara, Miguel and Paulo) gave correct answers. When we look at the justifications given by students, we see that, before the interaction, no student gave a correct justification, that is they did not know why the fact that the air cooled inside the balloon made it going down.

After the interaction, four students showed knowledge changes. Two changed their common sense option, one (Sónia) to the correct conception and another (Nuno) to the incomplete conception. The other two (Sofia and Miguel) changed their wrong justification to their correct choice to a correct justification.

Globally, the results showed that only two students, both from a low socio-economic status and with low achievement (Raquel and Carlos) did not change their conceptions.

The levels of recognition were the same before and after the visit (levels II and I). After the visit, the levels of passive and active realization increased for some students. Sónia and Nuno, who did not possess passive realization, were able to acquire it and Paulo passed from degree I to degree II. No student possessed active realization before the visit; after the visit Sofia and Miguel attained degree II and Sara and Nuno degree I.

*The Hydrogen Rocket.* The constitution of the water molecule, the water electrolysis and the concept of combustible were the concepts involved when working with the hydrogen rocket. In order to obtain a global view of the results, we show in figure 8 the comparison of the categories of answers given by students and respective degree of specific coding orientation, before and after the visit to the museum.

STUDENT'S CONCEPTIONS AND SCO

| STUDENTS | WATER'S MOLECULE CONSTITUTION | | | | COMBUSTIBLE EXAMPLES | | | | | | WATER ELECTROLYSIS | | | | | | SCO | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CATEGORIES | | | | CATEGORIES | | | | JUST. | | CATEGORIES | | | | JUST. | | RR | | PRL | | ARL | |
| | CS | W | I | C | CS | W | I | C | Wr | Cr | CS | W | I | C | Wr | Cr | B | A | B | A | B | A |
| Sofia | | | | ● × | ● → | → | → | → × | ● | × | ● × | | | | ● × | | I | II | I | II | - | I |
| Raquel | | ● × | | | ● × | | | | ● × | | ● × | | | | ● × | | - | - | - | - | - | - |
| Sara | | | | ● × | | | | ● × | ● × | | ● × | | | | ● × | | II | II | II | II | - | - |
| Sónia | | | ● × | | ● × | | | | ● × | | ● → | → | → × | | – – | | I | II | - | - | - | - |
| Miguel | | | | ● × | ● → | → | → | → × | ● → | → × | ● → | → | → × | | ● × | | I | III | I | II | - | I |
| Carlos | × ← | ← | ← | ● | ● × | | | | ● × | | ● × | | | | ● × | | I | - | I | - | - | - |
| Nuno | | | | ● × | ● × | | | | ● × | | ● → | → | → × | | ● × | | I | II | I | I | - | - |
| Paulo | | ● → | → | → × | ● → | → | → | → × | ● × | | ● × | | | | ● × | | - | II | - | II | - | - |

*Figure 8* **–** Student's conceptions concerning the constitution of the water's molecule, examples of combustible and water's electrolysis process and their sociological meaning in terms of SCO.

Notes:

**Conceptions about the water's molecule constitution:**
CS - Oxygen
W - Carbon and Helium
I - Hydrogen
C - Hydrogen and Oxygen

**Conceptions about combustible examples:**
CS - Petrol
W – Water and Carbon Dioxide
H - Hydrogen
C - Hydrogen and Petrol

**Conceptions about the process of water's electrolysis**
CS – Letting water boil
W – Heating it
I – Transporting electric current into the water
C -Transporting electric current into and out the water

**Conceptions:** CS – Common sense; W – Wrong; I – Incomplete; C – Correct; **Justification:** Wr - Wrong; Cr - Correct; **(SCO) Specific coding orientation:** RR – Recognition rules; PRL – Passive realization rules; ARL – Active realization rules; B – Before the visit to the science center; A – After the visit to the science center; **Symbols**: **(●)** - Before the interaction; **(×)** – After the interaction; **(→)** – Direction of evolution.

Students' recognition was low before the visit to the museum (degree I for most students and degree II for only one). This means that common sense conceptions were the most valued. With the exception of Carlos, all students with high achievement, that is Sofia, Sara, Miguel and Nuno possessed passive realization although in a reduced degree (degree I and II). This means that, these students had the most correct conceptions. There was a total absence of active realization for all students.

The evolution was not great after the visit, considering that most changes occurred from degree I to II and that the highest degree (degree III) was only present once. Sofia, Sónia, Miguel and Nuno stood out by increasing recognition after the visit. For Sofia, Sónia and Nuno there was an increase of one degree, from I to II, and for Miguel an increase of two degrees, from I to III. With respect to passive realization, Sofia and Miguel stood out by increasing one degree, from I to II. These two students were the only ones who showed to have active realization, although in a low degree (degree I).

Carlos constituted a particular case in relation to the water molecule constitution. Although in a low degree (degree I), he showed to have recognition and passive realization. After the visit, however, it seems that he lost them. This fact, although strange, is interesting because it may point out to the influence of the interaction with the exhibits to develop misconceptions.

When we analyzed the justifications given, we saw that, before the visit to the museum, none of the students justified any of the options relative to the three scientific contents, which means absence of active realization. The interaction with the rocket did not lead students much further. Only two students showed to be able to justify, but only for the definition of combustible, therefore showing to possess active realization.

With regard to the evolution, before and after the visit, of students with distinct characteristics (socio-economic status, achievement and gender), the results indicate that, with respect to recognition rules and passive realization rules, both low socio-economic status and high socio-economic status students showed some improvement. However, the latter increased more than the former. In the case of active realization rules, only two students (Sofia and Miguel), from a low socio-economic status, increased understanding. With regard to gender and for all rules, both boys and girls increased understanding but boys increased more than girls. When we consider the achievement groups, we observed that, for recognition rules and passive realization rules, both low and high achievers increased, but the latter increased more than the former. In the case of active realization rules, only two students (Sofia and Miguel), both from low family socio-economic status and with high achievement,showed an increase.

*Relation between procedures and concept understanding*

Figure 9 shows comparatively the degree of SCO obtained in the two micro contexts of the study.

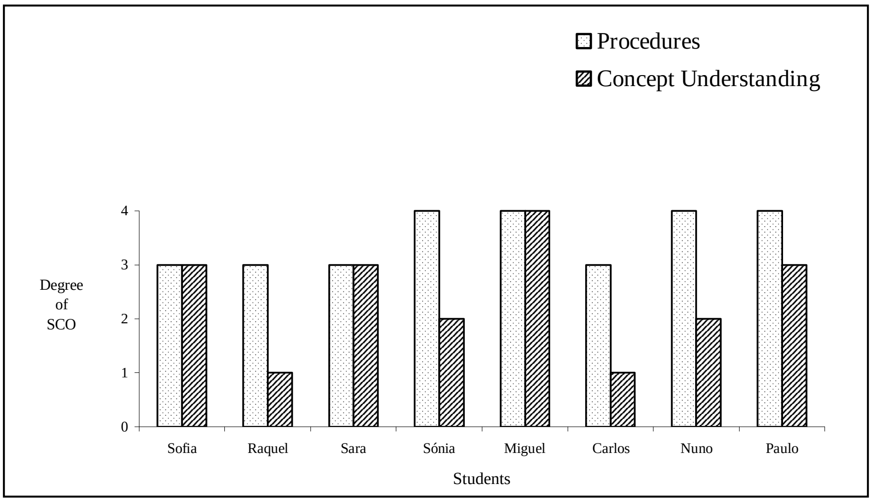



*Figure 9* – Comparison of performance (SCO) at the level of procedures and concept understanding.

The analysis of the graph shows that although, for some students, there seems to exist a direct relation between procedures and concept understanding, as is the case of Sofia, Sara and Miguel, this relation is not present in general. This means that what students do (procedures) seems not to have a direct consequence on what they learn (concept understanding). Students obtained lower results at the level of concept understanding than at the level of procedures. The graph also shows that there are no cases in which the results obtained for scientific learning were higher than the results for procedures.

## Discussion

*Student-exhibit interaction at the level of procedures*

*The Hot Air Balloon.* At the level of recognition, the high degree of recognition obtained suggests that students, in general, characterize the exhibit easily. We considered recognition as the identification of the exhibit title and the designation and function of the exhibit components. We believe that the design of this exhibit allow students to identify the context easily. This is a very important condition to obtain good results, and confirms the results of various authors (Falk & Dierking, 2000; Gilbert & Stocklmayer, 2001), about the importance of the exhibit design to the learning process.

The fact that at the realization level, socially disadvantaged students (Raquel and Carlos) attained better results than socially advantaged students (Sara and Nuno) may be explained by the fact that, for socially advantaged students, the impact of environmental novelty on learning in out-of-school settings was possibly inexistent. It may be that the museum is only one more context, among those many contexts they have already had access to, and therefore they have little curiosity with the interaction. On the contrary, for socially disadvantaged students, this context may be a unique experience of their lives and consequently curiosity and commitment may be greater. For them the impact of environment novelty seems to enhance learning. Many studies have demonstrated that a considerable amount of the learning that occurs in free-choice conditions is a result of novelty-seeking behavior (Anderson & Lucas, 1997; Kubota & Olstad, 1991). The results obtained in the study of students' socio-affective dispositions  supports this explanatory hypothesis by showing that socially advantaged students evidenced less favorable dispositions towards the interaction, in both cases, the balloon and the rocket. We can look at these dispositions as the personal influence on learning processes referred by Driver *et al* (1994) and Falk and Dierking (2000). Students' socio-affective dispositions seem to relate to their learning success.

The fact that some students, who have a high degree of recognition rules, did not revealed to possess realization rules could be related to the absence of the rules that allow to produce the text expected in this context, or they did have them and could not produce the text for some reason unknown to us. We should note that, these are the students who had less favorable socio-affective' dispositions, which may help to explain their results. To Bernstein (1990, 2000) students need to possess realization rules to produce the correct text. This is important because the recognition of the context is not enough to produce the expected text.

*The Hydrogen Rocket.* The fact that all students, with the exception of two students (Sofia and Miguel), showed to have an intermediate degree of recognition may be mainly a consequence of the fact that these students showed great difficulty in identifying both the name of the exhibit and the function of some of its parts. The design of this exhibit was more complex than that of the Hot Air Balloon. It was difficult to relate the exhibit to a hydrogen rocket. First, the object simulating the rocket (number 2, figure 4A) did not have physical characteristics similar to a true rocket. It was a small plastic piece without any decoration. Second, the students could not relate the hydrogen to the combustible, which move the object, because the hydrogen was not visible. Students simply saw a transparent liquid –water- (number 4, figure 4A) and the bubbles, which came out of the water, but these bubbles were not of easy perception. It was then very difficult for students to establish a relation between the liquid and the combustible. Some of the functions of the components are not of easy identification. The glass of the water's recipient was partially misty and this did not allow an adequate visibility. Once again, the results evidenced the importance of the design.

We could explain the intermediate degree of passive realization with the fact that, during the interviews, when we asked students about the procedures, which were necessary to put the exhibit working, they did not select the reading of the instructions as a necessary procedure. This reveals the possibility of students having not attributed importance to the reading of labels, as a procedure to follow. Although there was an intermediate degree of passive realization, the degree of active realization was in general high. We think this aspect is very important.

*The two exhibits.* When we look at the interaction with both exhibits, the easier recognition showed by students in the context of the balloon, when compared with the recognition in the context of the rocket, seems to be explained by both the specific characteristics of each exhibit and the results obtained at the level of students' socio-affective dispositions in relation to the tasks required. The set of mechanisms inherent to the functioning of the balloon were visually simpler to the students than the procedures of the rocket. The other characteristics of the rocket we have mentioned seem also to justify the results. In the case of the balloon, the mechanisms, which permit the heating of the air, were placed inside the exhibit, making difficult for students to understand how the air was heated. On the other hand, the phenomena associated with the going up and down of the balloon seem to be simpler than those of the rocket. This may explain students better results in the case of the balloon.. The fact that most students, when answering the questionnaire, said that they had understood what happened during the interaction with the balloon but they did not understand it in the case of the rocket may also explain differential results.

With regard to the realization, the absence of differences in the passive dimension may be the result of the fact that all students select the necessary procedures to the correct functioning of the exhibits with the exception of the reading of the instructions. The high degree of passive and active realization may be the result of one of the sociological characteristics of the two exhibit contexts. The evaluation criteria were characterized by very strong framing, that is it was explicit to students what are the procedures they should follow to put the exhibits to work. As pointed out by Falk (1997), the reading of the label with the instructions seems a fundamental procedure in order that students know what they are going to do. This study confirms that labels should specify the procedures and their sequence.

Based on the results obtained in the case of active realization, we could find two behaviors related to the correct functioning of the balloon. Some students did not read the labels with the instructions and did not wait until the temperature reached 90ºC to press the button to release the balloon. It was necessary to wait about six or seven minutes for the temperature to reach that value. Moreover, students should keep their finger on the button during that time. The fact that most students considered, in the questionnaires results, that they had spent too much time with the balloon and, that that time was enough in the case of the rocket, confirms our perception. This happened with Sofia and to Sara who, in the case of the balloon, did not wait for the temperature to reach 90ºC to press the green button. The fact that some students did not read the instructions may explain the lower results with the balloon. There is the exception of Carlos who showed a degree of active realization higher in the case of the balloon than in the case of the rocket.

The fact that, in the case of the balloon, students needed to hold down a button for six or seven minutes, shows a poor exhibit design. It is clear that few students will wait that long in the context of a visit to an exhibition. Designers should be aware that 'details' as these can prevent the success of an exhibit. Teachers should also be aware that they must be critical of the organization and structure of exhibitions to which they take their students.

*Student-exhibit interaction at the level of concept understanding*

*The Hot Air Balloon.* A positive evolution from entry to exit, occurred with the six students, for the three rules, and this could be related to the exhibit characteristics, particularly to the information given to students in label instructions, and the possession of SCO.

With respect to the exhibits characteristics, the first step of instructions indicates "press the red button to obtain hot air" and the second indicates "wait until the air reaches 90ºC". These instructions informed the students that the air heats. However, only two options for the balloon going up, incomplete and correct, used the 'hot air' expression, leading us to think that this may explain the results obtained. The four lowest achievement students did not understand the reason why the balloon goes up. If the expression "inside the balloon" had been added to the first step of instructions (press the red button to obtain hot air inside the balloon) these students might have achieved better results.

The difficulty that most students felt to understand why the balloon goes down may be related to the fact that nothing, in the instructions, point out to this phenomenon.

The results evidenced the influence of students' achievement and socio-economic status on students' performance. They may have developed realization rules to the context of concept understanding, in other situations, namely in the school, to produce the expected text, in this context.

*The Hydrogen Rocket.* A positive evolution, from entry to exit in the center exhibit, occurred with five students, and that evolution was evident, especially at the level of recognition and passive realization rules. This may be related to the exhibit characteristics, in particular to information given to students and that was presented in the instructions, and also to the presence of SCO.

With regard to exhibits characteristics, the instructions presented indicated "turn the handle until you have enough rocket fuel (when the lights go green)" and the explanation given was "you are producing electricity witch transforms the liquid into gases, hydrogen and oxygen. When you press the button, the gases mix and have an ignition. Various types of space rockets use the hydrogen as fuel". We do not find any reference to liquid as being water. This should have been clarified by designers. If students knew the water constitution, we think they have learned it out of the science center, as revealed by the results. As Carlos' results point out, it is important to assure that student-exhibit interaction does not contribute to confuse the correct students' conceptions.

With respect to the combustible examples, the fact that only three students have learned, after the interaction, that the hydrogen is a combustible may mean that students did not read the label. The "what happen?" label section indicated the "hydrogen as fuel". The only information present on the label that helped to explain why the hydrogen was a combustible was "the gases mixed and have an ignition". This information is so vague that we think that does not help students to obtain the answer. They are only able to learn the example. The same happened with the water electrolysis. The sentence "you are producing electricity which transforms the liquid into gases, hydrogen and oxygen" present in the label does not explain why this happened.

The results evidenced the influence of students' achievement. Good achievers obtained the best results. As with the balloon, it may be that they have already acquired the realization rules to the context of concept understanding in other situations, as in the school, which helped them to produce the expected text in this context.

*The two exhibits.* The results of the answers to the two questionnaires seem to show (1) a relation between the use of interactive exhibits and the understanding of scientific concepts, (2) some influence of sociological characteristics related to the family (socio-economic status) and related to the school (achievement) on that relation, (3) a relation between the possession of recognition and realization rules and the understanding of scientific concepts. These results point in the direction of facing interactive exhibits as potential tools to use in the understanding of scientific concepts and in decreasing the gap between socially differentiated students.

Whereas socially disadvantaged students (Raquel and Carlos) revealed high socio-affective dispositions at the level of procedures, consequently obtaining good results at that level, we observed that these students attained the worst results at the level of concept understanding. This is an interesting point for analysis. It seems that these exhibits have some limitations for disadvantaged students, at the level of concept understanding. Therefore, we need to think at both, what is it that exhibits need to change to promote the understanding of scientific concepts by these students and what are these students needs to learn scientific concepts, through science exhibits. They had socio-affective dispositions to interact with exhibits at the level of procedures but they revealed absence of recognition and realization rules at the level of concept understanding. We must ask why that happens. Sociological characteristics of the exhibits may be a reason. At the level of concept understanding, the evaluation criteria were not explicit, that is it was not clear to students what they were expected to understand and to learn.

*Students' procedures and concept understanding*

We observed that what most students did (procedures) did not have a direct consequence on what they learned (concept understanding), that is values obtained in the micro context of procedures do not correspond to values obtained in the micro context of concept understanding. One reason for this discrepancy may be found in the sociological differences of the exhibits at the level of procedures and concept understanding. Whereas in the context of concept understanding, the evaluation criteria were regulated by a weak framing ($F^{--}$), in the context of procedures they were regulated by a strong framing ($F^{++}$). This means that the evaluation criteria are more explicit to the students at the level of procedures and this may facilitate the carrying out of the activity. The evaluation criteria were not explicit at the level of concept understanding, that is it was not clear to students what they were expected to understand and to learn. It is therefore understandable that results at the level of concept understanding were lower than at the level of procedures.

Another aspect to consider is that what students could see or do in the exhibit helps little to understand the scientific concepts involved in it. We think that it is important to define precisely the exhibit aim. This would help science centers educators and teachers to concentrate on what and how they must act to help students.

## Conclusions

This study investigated the influence of some characteristics of students, exhibits and students-exhibits interaction on students' learning, when they interact with two exhibits at a science center. With respect to students' characteristics, we were unable to reach definitive conclusions, although students' family background and achievement appear to influence students learning with exhibits. Socially advantaged and disadvantaged students react differently to each micro-context. We need further studies to get a deeper understanding of that influence and to help designers to conceive exhibits that allow the reducing of learning differences originated by these characteristics of students.

The study allowed us to identify the influence of the specific coding orientation (SCO) on students' performance. The possession of recognition and realization rules showed to be a crucial factor on students' performance. Such possession is related to some characteristics of the exhibits and of the students, and to the learning context. Further studies are also necessary to clarify this relation.

Although the analyses revealed, in general, changes in concept understanding, from entry to exit, a more detailed analysis revealed that gain was not evenly distributed across all eight students. Deeper studies are necessary to clarify our findings and help to understand how students with different characteristics learn from exhibits, essentially the most socially disadvantaged students.

We identified three exhibits' characteristics, that influence students' learning, that are related to their design, the set of mechanisms inherent to the functioning of exhibits and the evaluation criteria. These are characteristics that can be analysed in future studies, as they may contribute to science educators' understanding of students' behavior, students' learning, and students' interactions with the exhibits.

With regard to the exhibits design, the analysis of the results suggests that distinct parts of exhibits, essentially those that are related to the knowledge that is to be learned, must allow students to easily associate them with the objects they are supposed to represent. For example, if the designers want students to think that an object simulates a rocket this object must have characteristics that easily allow its association with a rocket, not leaving it to the students' imagination. Text in the exhibit label must contain words or/and expressions that help students to construct the scientific concepts involved in it.

The mechanisms and facts that students have to learn, in order to understand a given concept, must be clear. This did not happen in the case of the exhibits which were object of this study, particularly in the case of the hydrogen rocket. Teachers and science centers educational teams must consider these aspects.

Evaluation criteria showed similar values for both exhibits but the values differed between the two micro-contexts: students' procedures and student's concept understanding. These distinct values seemed to explain the distinct performances observed in each micro context. If the evaluation criteria are not explicit, how can the principles that allow recognition of the context and production of the expected text be acquired? We think this is an important point to be explored in the exhibits conception. If we want to help students to understand scientific concepts we need to construct exhibits that offer explicitly that possibility. The evaluation criteria also affected the relation between what students do (procedures) and what students learn (concept understanding). We can conclude that good performance in both micro contexts requires explicit evaluation criteria, that is students must know what is expected from them in relation to what they need to do (procedures) and in relation to the facts or concepts they are expected to learn (concept understanding).

Another contribution of this study is its innovative form of analysis of exhibits-students interaction and students' learning. Bernstein's theory made possible to identify some important sociological aspects of the students-exhibits relation and relate them to students' performance. This theory has shown to have a strong potential to study learning contexts and we suggest that this applies to science centers. It makes possible the understanding of what students do and learn and how they do that. According to Bernstein, the acquisition of recognition and realization rules is a function of the classification and framing principles. In this study, the classification between contexts (between common sense and school concepts at the micro context of the concept understanding and between the various exhibits parts at the micro context of the procedures) made possible for students to manifest easily recognition rules for both micro contexts. With respect to framing, that is the nature of the control upon selection, sequence, pacing and evaluation criteria, we conclude that, its values for both micro contexts, except in the case of the evaluation criteria, made possible for students to show passive realization. This means that students could identify the correct answer to school concepts (at the micro context of concept understanding) and identify the correct behaviors (at the micro context of the procedures). The critical point is related to evaluation criteria as we discussed above. At the micro context of concept understanding, a weak framing value ($F^{--}$) did not seem adequate for the acquisition by students of a correct understanding of concepts. We suggest that exhibits at a science center make explicit the knowledge that is expected that students learn.

This study contributes with some knowledge about science centers' learning and provides some paths for future research. The results and their discussion suggest important aspects that exhibit designers, and science centers educational teams must take into account when devising interactive exhibits directed to visitors in general and to students in particular. In this case, the role of the teacher, who might be considering incorporating the non-formal learning setting into school's curriculum, is also important. If teachers spend time and energy to take students to science centers and expose them to a set of exhibits, then what are the returns the teacher might expect, in terms of students' increased understanding of scientific concepts? There are also implications for teachers action related to the fact that students from lower socio economic status may experience a novelty factor in visits to museums, while other students may not.

From the findings emerged the idea that interactions with exhibits may influence the development of misconceptions. This may be useful to considerer in futures studies.

In conclusion we suggest that future efforts to investigate learning at science centers should consider characteristics of students' achievement and family socio-economic status. Similarly, we suggest that they should consider exhibits characteristics, at least the set of mechanisms that students must learn in the interaction and the evaluation criteria concerning the text to be learned.

## *NOTES*

1. For example, some science centers are organized to have rooms for Physics and rooms for Biology. In this case, there are strong boundaries between discourses. In some other science centers, there are rooms where Biology and Physics are explored simultaneously. Here there are blurred boundaries between discourses.

2. For example, if we consider the exploring of space by students, teachers can control that exploration or leave to students to do it by themselves. In the first case, the framing is strong and in the second, the framing is weak.

3. Selection refers to knowledges and competences to be learned; sequence to the order in which learning takes place; pacing to the expected rate of acquisition and evaluation criteria to the correct/legitimate text to be acquired and produced.

4. The ESSA Group (Sociological Studies of the Classroom) of the Department of Education of the School of Science University of Lisbon carries out research on science education, within a fundamentally sociological approach and its interface with other approaches.

5. In this study, the socio-economic status should be understood as nominal, descriptive, and not as an analytical concept, used to make evident its role as a regulative category of the differential codes of family and school.

6. We constructed a 1-6 scale for both mother and father's occupation and academic qualification. The maximum of points obtained would therefore be 24.

7. We used a four-degree scale because we had a 100% value. According to Del Rincón *et al* (1995), the best way to determine the number of degrees on a scale is to make its points equidistant.

8. We used a three-degree scale because the total value was eleven. According to Del Rincón *et al* (1995), the best way to determine the number of degrees on a scale is to make its points equidistant. However, it is impossible to make a scale of eleven points where points are equidistant. Thus, we decided to create a three points-scale.

9. The results obtained at the level of socio-affective dispositions are shown in appendixes A, B and C. Space limitations led us to take them out of the section 'results', where they could have been described in detail. This description can be found in Botelho, 2001

# Appendix A

**During the time that you interacted with the exhibit, you**

(a) enjoyed yourself; (b) had fun yourself; (c) played; (d) learned new things; (e) felt it was useless; (f) felt it was annoying; (g) understood what was happening; (h) felt it was very complicated

(*Indicate yes or no; you may signal more than one sentence*)

STUDENTS' FEELINGS DURING INTERACTION

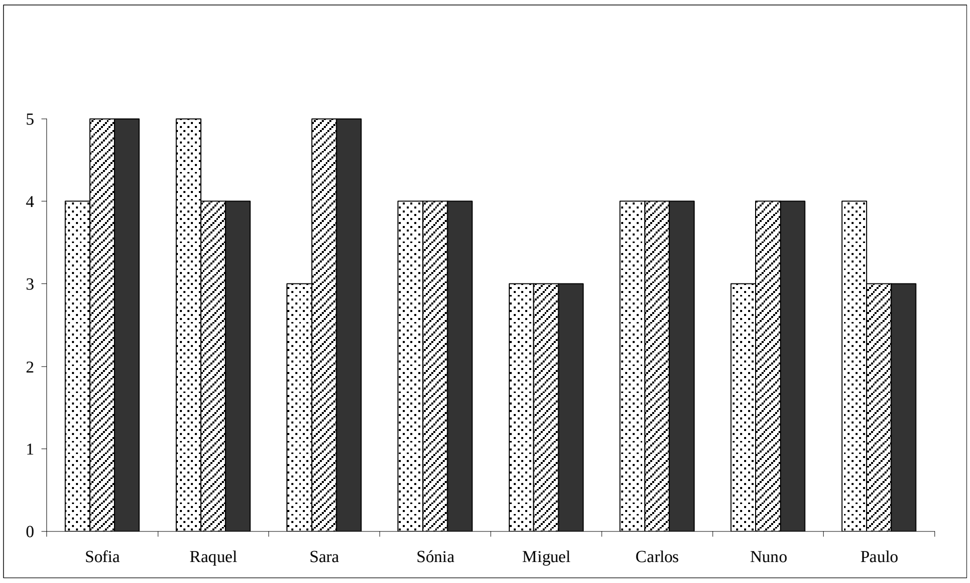
| During the time that you interacted with the exhibit, you | Sofia | | Raquel | | Sara | | Sónia | | Miguel | | Carlos | | Nuno | | Paulo | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | Y | N | Y | N | Y | N | Y | N | Y | N | Y | N | Y | N | Y |
| HOT AIR BALLOON | | | | | | | | | | | | | | | | |
| Enjoyed yourself | | ● | | ● | ● | | ● | | | ● | | ● | ● | | ● | |
| Had fun yourself | | ● | | ● | ● | | | ● | | ● | | ● | ● | | | ● |
| Played | | ● | | ● | ● | | ● | | | ● | | ● | ● | | | ● |
| Learned new things | | ● | | ● | | ● | | ● | | ● | | ● | | ● | | ● |
| Felt it was useless | ● | | ● | | ● | | ● | | ● | | ● | | ● | | ● | |
| Felt it was annoying | ● | | ● | | ● | | ● | | ● | | ● | | ● | | ● | |
| Understood what was happening | | ● | | ● | | ● | | ● | | ● | | ● | | ● | | ● |
| Felt it was very complicated | ● | | ● | | | ● | ● | | ● | | ● | | | ● | ● | |
| HYDROGEN ROCKET | | | | | | | | | | | | | | | | |
| Enjoyed yourself | | ● | | ● | ● | | ● | | | ● | | ● | ● | | ● | |
| Had fun yourself | | ● | | ● | ● | | | ● | | ● | | ● | ● | | | ● |
| Played | | ● | | ● | ● | | ● | | | ● | | ● | ● | | | ● |
| Learned new things | ● | | | ● | | ● | ● | | | ● | | ● | | ● | | ● |
| Felt it was useless | ● | | ● | | ● | | ● | | ● | | ● | | ● | | ● | |
| Felt it was annoying | | ● | ● | | ● | | ● | | ● | | ● | | ● | | ● | |
| Understood what was happening | ● | | ● | | ● | | ● | | ● | | ● | | ● | | | ● |
| Felt it was very complicated | ● | | ● | | | ● | ● | | ● | | ● | | | ● | ● | |

## Appendix B

**Students' opinions about Hot Air Balloon looking/design and time spent in interaction**

1. I think the exhibit was:
   (5) very pretty; (4) pretty; (3) normal; (2) ugly; (1) very ugly
   (5) very funny; (4) funny; (3) normal; (2) not funny; (1) not at all funny

2. From the moment I started working with the exhibit until it went up, I think it took
   (5) too much time; (4) much time; (3) enough time; (2) little time; (1) much little time

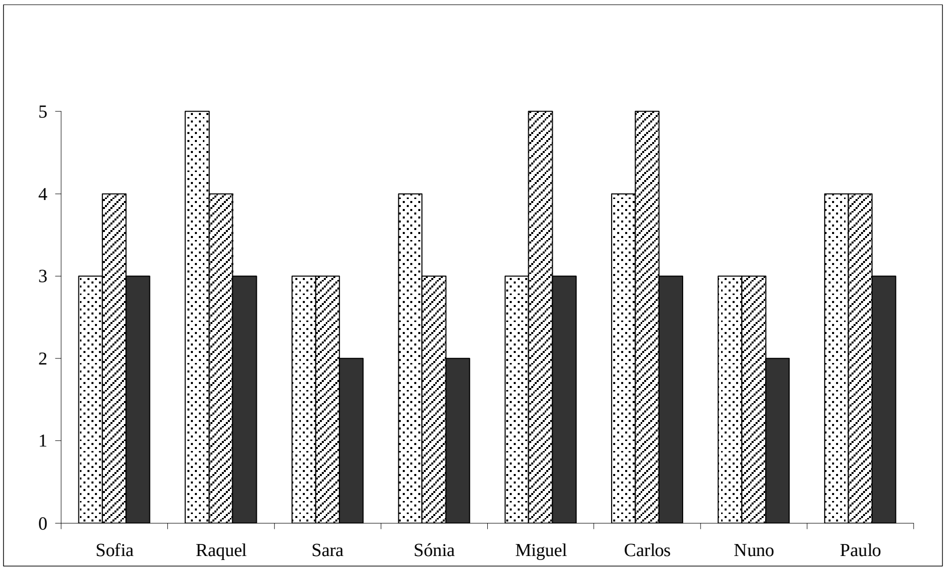


# Appendix C

**Students' opinions about Hydrogen Rocket looking/design and time spent in interaction**

1. I think the exhibit was:
   (5) very pretty; (4) pretty; (3) normal; (2) ugly; (1) very ugly
   (5) very funny; (4) funny; (3) normal; (2) not funny; (1) not at all funny

2. From the moment I started working with the exhibit until it went up, I think it took
   (5) too much time; (4) much time; (3) enough time; (2) little time; (1) much little time



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## Abstract

The paper describes a study which investigates students' learning during interaction with two exhibits at a science center. Particularly, it analyzes both students' procedures, when interacting with exhibits, and the understanding of scientific concepts present in exhibits. Bernstein's theory of pedagogic discourse (1990, 2000) gave the sociological concepts to characterize the students-exhibits interaction and allowed the analysis of the influence of the characteristics of students, exhibits, and interactions on students' learning. Eight students (ages 12-13) with distinct sociological characteristics participated in the study.

Some evidences emerge from the results. First, the characteristics of students, exhibits, and interactions appear to influence student learning. Second, to most students, what they did (procedures) seems not to have any direct consequence on what they learned (concept understanding). Third, the data analysis suggests an important role to designers and teachers in overcoming the limitations of the exhibit-student interaction.

*Key words:* Science Center; Exhibits; Specific coding orientation; Student's procedures; scientific concept understanding