Teaching Physics in Primary School – Problematization as a basis for experimental activities

B Railbolt1, R Cruz-Hastenreiter1,2 and F Rodrigues1,2

1UNIRIO, Departamento de Física, Avenida Pasteur, Rio de Janeiro, Brazil.
2IFRJ, Campus Rio de Janeiro, Rua Senador Furtado 121, Rio de Janeiro, Brazil.

Abstract. This work presents preliminary results of an investigation about the use of experimental activities, from problematization, in physics classes to primary school students. It is proposed initially a reflection about how experimental activities based on solving problems can contribute to the teaching of sciences from a broader perspective. Based on this reflection, three experimental activities are proposed, starting from problem situations, where are presented concepts of Physics involved in the siphon effect, in the shadows formation and the rigid body equilibrium, directed to Elementary School. The proposal of the activities aims to explore conceptual, social interaction, epistemological and relationship with daily life dimensions present in didactic approaches based on inquiry-science teaching. In an empirical essay, we present some results of a didactic action. The construction of data from discursive interactions was used as a methodological reference, and content analysis was used as a data analysis tool. In the analysis of the results, recorded episodes were verified with the production of small texts and pictorial representations (drawings) made by the students.

1.0 Introduction

While acknowledge the relevance of the numerous works that deal with Physics teaching in the initial series of Elementary School, specifically in Brazil, we highlight the importance of expanding the repertoire of research works in order to contribute with reflections that meet the fundamental questions related to the Physics teaching present in dissertations, theses, papers and official documents. In this context, and in order to incorporate new contributions, both from our theoretical and methodological framework and from the analyzes of the constructed data, the present research is inserted and finds justification and relevance.

The present work looks to build experimental activities based on the problematization. It was assumed as a didactic approach the inquiry-science teaching, in which, in addition to the conceptual perspective, the epistemic and social perspectives are also contemplated. It is necessary to teach beyond scientific concepts. It is considered fundamental to incorporate didactic activities actions that allow a certain appropriation of the scientific language, specific to this particular knowledge. As Capecchi and Carvalho affirm, "Learning the sciences is also appropriate for this new language and it is through space that speech becomes appropriate becomes possible" [1]. (p.172).

Official documents corroborate this teaching perspective: In this sense, it is not enough that scientific knowledge is presented to students. It is necessary to offer opportunities for them, in fact, to engage in learning processes in which they can live some investigation moments experience that enable them to exercise and broaden their curiosity, to improve their capacity for observation, logical reasoning and creation, to develop more collaborative positions and to systematize their first explanations about the natural and technological world and their body, their health and well-being, having as reference the knowledge, languages and the procedures of the Natural Sciences [2].
The purpose of this research, therefore, will essentially be to evaluate the possibility of working on Physics concepts from the most elementary levels of Basic Education, based on an investigative and problematizing approach. The present work is part of this group and aims to bring new reflections about the theme and contribute with new results. Therefore, specifically, we try to answer the following questions: How can the pressure concepts, shadow formation and equilibrium be complexed from an investigative approach for students in Elementary School? Besides the conceptual dimension, what other dimensions can emerge from the proposed experimental activities?

In this work, we intend to observe the student’s performance during the research activities and, from the observations, to search for elements that allow the learning evaluation in the dimensions: conceptual, social interactions, epistemological, relationship with daily life.

2. Theoretical Framework
Experimental activities related to the contents of physics have been developed based on the approach Inquiry Science Teaching (IST), and from a perspective of problematization. The IST appeared in the middle of the 20th century as a strategy to implement in the classroom. In this pedagogical approach, the scientific concepts presented concern only one of the dimensions worked. From this perspective, the learning objectives are broader, including the perception of making science a human activity and the understanding of the need to devise "ways" of doing it. The epistemological, social and conceptual dimensions are incorporated here. According to IST, you must learn to observe, plan, formulate a hypothesis, think, argue, and to create explanatory models. Basically, it is necessary that students be genuinely committed to the proposed activities [1].

The objective of the IST is scientific literacy, not the training of scientists. The importance of investing in activities that gives students the working experience for themselves, dealing with error, since for this teaching perspective, error is seen as an essential part of learning. The error encourages students to think and seek to answer their doubts, giving them intellectual freedom to build their operations [3].

The investigative nature activity is a strategy, among others, through which the teacher diversifies his practice in the daily school life [4]. Such a strategy encompasses all activities, which are basically centered on the student, enable the development of autonomy and the ability to make decisions, evaluate and solve problems, appropriating concepts and theories of the natural sciences.

2.1 Problematization and problem-situation
According to the adopted perspective, the problem-situation is, on the one hand, the essence of the generation in science knowledge, and on the other hand, it is the center of didactic reflection. For Fabre (1999), the problem-situation rests on two axes, the didactic and the pedagogical. The first one is based on epistemological questions, which in the case of science teaching provide elements that elucidate the knowledge to be taught, and the second is based on questions of cognitive psychology. The perspective pointed out by some French authors [5], [6], [7], [8] and [9]) brings to the center of the epistemological discussions the concept of obstacles according to Bachelard. For these authors, the relation between the epistemological and psychological bases allows the first representations or models that will be interpreted only in terms of obstacles [10]. Therefore, a problem-situation must be thought in the sense of "making emerge" in the student’s representations the alternative conceptions, the epistemological obstacles in Bachelard’s sense. The situations must be based on problems of a concrete nature, and especially that they are in fact perceived by the students as relevant. "To build a situation is to construct a medium within which the knowledge taught can have a perfect meaning for the student" [7]. (p. 9)

For [6] and [7], it is necessary to distinguish the two levels present in the concept of problem claimed in the present work, namely problematization and resolution. According to this perspective, it is fundamental that students participate in the so-called problematization phase, only then will they understand the problem as theirs. It should be stressed, however, that the problematization in this context assumes a methodological systematization of the problem-situation.

Problematization in the sense attributed by [11] is much more complex and can be a present function, both in the production activity of scientific knowledge (activity of the scientist) and in the activities of
science classes with a problematization approach. In this aspect, problematization includes what the author calls: empirical registry; model records; explanatory registration.

Unlike a traditional approach, in which the possible empirical registry and the model records are given a priori, it’s representative for the student to describe (often only reproduce) the explanatory registration, in a problem-situation the dialectical relation empirical register - model records is built by and with students. The second phase, called resolution, is already present in the scheme presented in Figure 1. After all, the three registration levels contemplate simultaneously the phases of problematization and resolution.

The perspective of problematization is included in the reflections of this work, considering that it is present both in the activity of production of scientific knowledge (activity of the scientist) and in certain activities of science classes [6]. We highlight that problematization in this context implies a methodological systematization of the problem-solving. In this aspect, problematization includes that [11] pointed out as: empirical record; registration of models; explanatory records. The figure 1 presents a simplified diagram of the interrelation of actions registers.

![Diagram of records](translated from Orange, 1994, cited in Orange, 2006, p.77)

### Figure 1: Scheme of "records" to problematize.

2.2 The experimental focus and epistemological dimension

The experiment can basically play two sides of the same coin during the development of problem-situation activities. The first one concerns the demonstration made by the teacher in order to highlight a particular phenomenon. However, the fundamental role of the experiment in this type of activity, is the role played in the validation phase of the proposals. In this case the experience assumes a supporting role, or better of reinforcement to certain explanatory proposals of the problem. It should be emphasized that in this type of activity, whenever possible, students should be included in the elaboration of the experimental script, if it exists. According to this perspective, didactic sequences of physics based on problem-situations are usually constructed from a series of experimental situations [10].

In the epistemological dimension, the activities are developed in line with current experimental
practices, evading an immediate (naive) inductivism present in several traditional experimental practices aimed at the physics teaching, and approaching a hypothetical-deductive epistemology.

From the epistemological standpoint, we note that this device tries to construct an experimental relation more aligned with the current practices. Indeed, it depends on the primacy of the theoretician over the experimental, thus abandoning the empiricist view still widespread among teachers. Thus, the questioning practice, the experiment construction within an initial theoretical framework (the student’s conceptions) makes it possible to illustrate the notion of the scientific problem. In addition, group work offers students an image of scientific practice. On the one hand, the research product of a team is shared with the entire scientific community. On the other hand, knowledge is a construction process that requires communication and validation between individuals [10]. (p. 21)

In this way, experience in activities based on problem-situation plays a fundamental role in the sciences teaching, and in particular in Physics. This is no longer just an instrument for the validation of proposals and becomes an integral element of these activities. The experience presents itself as mediator of knowledge, but it is like an experience based on the social practice of reference1 that is a scientific science. Therefore, from these activities, students have the opportunity to learn, in addition to concepts related to Physics, social practices associated with the production of knowledge in the area. This can be extended to other knowledge areas, in view of each particular epistemology.

3. Methodological Framework
The present work is qualitative investigation. In an empirical essay, we present some results of a didactic action applied to students aged 9 to 11 years old. The data were constructed from the discursive interactions obtained from the audio and video recordings of the experimental activities, as well as from the textual and pictorial representation made by the students after the didactic action. As a methodological reference for the analysis of the data, the content analysis, according to [12] perspective, was used. The theoretical methodological framework constructed from IST and problematization contributed to the creation of the unit of analysis and the initial categories, which contemplate its dimensions: conceptual; epistemological and social interaction.

The activities application was based on the physical knowledge classes proposed by [13]. The author proposes some important steps for the development of the activity:

1º- The materials presentation;
In this step the teacher presents the one-to-one materials that will be used in the experiment.

2º - The teacher proposes the problem;
The Educator shows the objective to be achieved by asking the problem-situation.

3º- Acting on the objects to see how they react;
The students, divided in groups, manipulate the materials previously presented by the teacher on their bench.

4º- Acting on the objects to get the desired effect;
After visualizing each material, the students act on them in order to solve the problem proposed.

5º- Becoming aware of how the desired effect was produced;
With the achievement of success or not, students are raising hypotheses seeking explanations already known for such phenomenon.

6º- Giving causal explanations;
The teacher will argue the students, asking how they obtained such a result, and the possible explanations of why.

7º- Writing and drawing;
At the end of the activity, each student will individually make a brief text representing it with a drawing containing the activity performed and what he learned from it.

1 The concept of reference social practice refers to social activities that can serve as reference to school activities (Martin and 1986 cited in [10]).
8º- Relating activity to daily life.

To materialize the activity, the teacher can relate this phenomenon or situation to the daily life of each student. So when he comes across what will happen, he will remember, and that will no longer be something abstract in his mind.

According to this methodological approach, students, divided into groups, should handle the material freely, observing the results. In attempting to solve the problem, students present their predictions, and acting in groups, seek the solution to the problem. At the end of the activity, the class is divided into a semicircle, and the teacher, at that moment, should stimulate them to describe, how they arrived at the particular solution, and the possible whys for the effect found. At this stage, two questions should be part of the students' explanatory statements, namely the questions "How?" And "Why?". Finally, individually, students should systematize the whole process involved in the activity by means of a brief text and a pictorial representation.

4. Experimental Activities

The following proposal aims to build didactic activities that start from concrete problems. The presented questions have specific characteristics according to the perspectives of the didactic devices present in this article, and adapted to the age range of the students to which they are destined. Therefore, the presented activities should be considered as an empirical essay based on the theoretical reflections brought in this work. It was tried to incorporate problem-situation elements present in the activities of IST.

4.1 The Siphon Effect

In this activity, the central concept is pressure, fundamentally, hydrostatic pressure. It is reinforced that this is an activity aimed at students in the Elementary School (age group of 9 to 11 years old). With this, the conceptual rigor in this activity is not the most important, after all the present effect to be understood can use a mathematical formalism not yet developed in the mentioned series, thus becoming inadequate such an approach. It is more important, from a problem-situation perspective, the elaboration of empirical registry and model records in the construction of explanatory registration.

The experimental activity suggests as an initial challenge: "Transfer the water contained in one container to the other". It is hoped that this initial challenge will be solved with some ease, after all it is enough to lift the full container, approach it from the void and pour it. In an attempt to make simple procedures rational, in this case, each group of students is asked to explain "how" they resolved the challenge and "why" they did so. Then the second challenge is proposed: "If the container filled with water is very heavy (making it impossible to handle it), or if it is fixed to the table, how can the liquid contained in it be transferred to the other container?" For this use of the aid of some materials, in addition to the transparent containers, as for example: a transparent plastic hose, a bucket with water and a tray (slope). In a way, the availability of the material in order to solve the second challenge seems to induce the solution, which reduces the authenticity of the students' actions.
4.2 The Shadow Theater
In this activity, instead of a physical concept, the rectilinear propagation of light principle is explored. Just as in the previous activity, this is an action aimed at students in the Elementary School (age group of 9 to 11 years old), and with that the rigor attached to the phenomenon does not apply either. The objective linked to the conceptual dimension prioritizes the perception of the relation between the relative distances of the light source; of the object to be projected; of the screen, and the dimensions of the projected shadow. The other objectives are similar to those of the previous activity. The difference of the previous activity is fundamentally in the challenges, that for the shadows theater we have as to reproduce in the screen of the projection the picture presented by the teacher.

Despite the general characteristics of the institutionalization stage, there are points of specificity in this stage. It is suggested as some examples to be pointed out by the professor the following: the phenomena of eclipses; and resolution of a practical problem of measuring heights of buildings and trees.

![Figure 4. The picture presented by the teacher.](image1)

![Figure 5. Acting and find a solution to the problem.](image2)

4.3 Objects on a balance
In the proposal of the third activity, the conceptual dimension deals with the physical concept of torque or moment of force. Similar to the previous activities, this is an action aimed at students in the Elementary School (age group of 9 to 11 years old), and with this, as already highlighted, rigor linked to concepts once again not applicable. The objective linked to this dimension prioritizes the perception of the relationship between the masses and the related distances in the respective equilibrium situations.

For this activity the materials used are: a wooden scale with a central hole and equidistant holes; modeling clay; straw hats to aid in the storage of the clay (or something that fulfills the function); dressmaker's ruler or tape measure; kitchen scale. As a problem, we have Challenge 01: "Is it possible to balance the two little hats containing different masses? "; as Challenge 02: the support of the "arm balance" will be repositioned to a hole other than the central one, and then the students are invited to construct a new equilibrium situation using the two little hats.

As pointed out in the previous activity, despite the general characteristics of the institutionalization stage, there are points of specificity in this stage. It is suggested as some examples to be pointed out by the teacher the following: The seesaw game between two children with different masses (the various possibilities); the presentation of some simple machines (wheelbarrow, scissors, ice picker, nutcracker) and the generalization of the moment of force.
5. Data Analysis

For the data construction, we counted on the dialogues recording in audio and with the researcher logbook annotations. Based on the theoretical-methodological references, and based on the empirical test carried out with the students, 4 or 5 categories were constructed for each analyzed dimension, as presented in Table 1. Most of the data were constructed from the discursive interactions obtained from the recordings in audio, later transcribed. From there, as a methodological reference for data analysis, the content analysis was taken as the basis. The creation of categories helped to analyze the data in the articulation of similar meanings and allowed the researcher inferences.

In an attempt to organize and systematize the processes of recording dialogues, data construction, categorization and inferences, we elaborate the scheme presented above in Figure 8.

The IST served as a basis for the categorical dimensions creation (conceptual, epistemological, social interaction and relation to daily life). The analysis of the data allowed the creation of categories (I, II, III, IV and V) related to these dimensions.
| Dimensions / Categories | I                                                                 | II                                                                 | III                                                                 | IV                                                                 | V                                                                 |
|--------------------------|------------------------------------------------------------------|-------------------------------------------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------|
| Epistemological perception | Experiment guides explanations                                   | Explanations based on personal perceptions, without direct mention of what was observed. | Explanations based on the group’s perception without direct mention of what was observed. | Explanations based on the teacher’s orientation, without direct mention of what was observed. | Explanations based on observation reinforced by the teacher’s orientation. |
| Conceptual Discussion     | No mention of the concepts involved in the activity.             | Mention concepts that are not directly involved in the activity.   | Mention to concepts that are directly involved in the activity, however incorrectly. | Mention to concepts that are directly involved in the activity in the right way.         |                                                                      |
| Social Aspect             | Preponderance in individual actions.                              | Search for collective solutions, internal to the group.            | Search for collective solutions, external to the group.               | Assistance from a more capable partner.                                           |                                                                      |
| Relationship between activity and daily life | Relate activity to daily life using a direct example correctly. | Relate activity to daily life using incorrect example.             | It relates the activity to the daily life indicating the perception of generalization of concepts involved. | It does not relate to daily life.                                                |                                                                      |

**Table 1.** Emergent categories of the theoretical framework

Following are some fragments from the transcriptions already in the interpretation phase. In this way, the mentioned fragments are accompanied by the inferences resulting from the reflections linked to the theoretical references. It is worth mentioning that in some of these are present, in addition to the students' statements, statements from the teacher that somehow linked generating questions.

**Teacher:** How did they manage to project shadows of the same size of things that are different in size?
**Student D:** Because of the distance. The flashlight was too close. When we did it the first time, it did not work. That's when **Student F** gave the idea of putting the flashlight there on the other bench.
**Student F:** Because the whale was going to be the same size as the fish. But she has to get bigger. The closer she gets to the flashlight, the bigger the shadow will be.

**Figure 9:** Fragment of audio transcription. Conversation between the teacher and students.

**Teacher:** Are the objects the same size?
**Student G:** No! The largest is the smallest. What you were seeing on the screen, which was the biggest, was the one here. We just pushed a little closer to the flashlight to look bigger. Actually, this one here is bigger. We takes a long time, to compare and make them the same.

**Figure 10:** Fragment of audio transcription. Conversation between the teacher and students.
In the "Shadow Theater" activity it was clearly possible to observe elements that characterized the presence of physical concepts directly involved with the activity, in a correct way. In figure 6, that is concrete evidence of the aspect seen on conceptual dimension Category IV. It was also observed elements that characterize the presence of Category II of the social aspect dimension, from the comment of Student D. Even though the main approach was not mathematical treatment, it was possible to perceive the idea of proportion between shadow size and object and its relation with distance from the light source correctly. It assumes that the student will be more easily seen in this analysis in the future. In figure 7, is concrete evidence of the aspect seen on conceptual dimension Category IV too.

The fragment presented in figure 6 makes it possible to deduce that the activity was carried out to a certain degree of collective form. The group turned to the teacher to help them solve the challenge. Student F seems to perceive the relationship between the distance and the size of the shadow projection. The relational explanatory record seems implicit.

6. Final Remarks
The present work seeks to incorporate experimental activities in science classes aimed at students of Elementary School. We seek from this initiative the scientific literacy of students in a broader conception. Attempts are made to incorporate activities into science courses that place students as agents of building their knowledge. Working together, the space for argumentation, the opportunity to share with colleagues from other groups, and the way in which they led to the resolution of a problem, brings aspects present in the activities of building scientific knowledge often inhibited in traditional approaches.

Experimental activities based on IST focused on primary school present themselves as a potential didactic tool that seeks to present science not only in its conceptual dimension. The preliminary results of the present study highlight other dimensions emergent of the activities, such as: the epistemological dimension and the interaction social aspects.

It is necessary to remember that the activity does not end with the accomplishment of the investigations; it is important to emphasize the importance of bringing students to reflection, allowing them to report what they have done, becoming aware of their actions and proposing causes for the observed phenomena. The role of students in teaching by research is fundamental: the engagement of the participants with the proposals brought by the teacher can transform a traditional and bureaucratic task into a task that generates learning about concepts and sciences [14].

The teacher’s objective is also of great relevance in the activities involving the IST. He moves away from the role of the knowledge agent, and acts as a mediator, working for the student to build their knowledge and seek their promotion through dialogue. In this work we highlight the institutionalization stage in which the teacher plays the role of science representative. It is at this stage that the teacher discusses with the students the answers given by the group, and negotiates the historically meanings shared by the scientific community. The knowledge systematization occurs at this stage.

We emphasize, however, the difficulty of incorporating investigative experimental activities involving Physics concepts for Elementary School, so that these activities are effectively a result of problematization. However, the initial results of our research show that this type of activity, in addition to incorporating epistemic practices in physics classes, presents great potential for student engagement and motivation.

7. References
[1] Capecchi M C V M and Carvalho A M P 2000 Argumentação em uma aula de conhecimento físico com crianças na faixa de oito a dez anos. Investigações em Ensino de Ciências. vol. 5 n.(3) pp 171-189.
[2] Brasil 2017 Ministério da Educação. Base Nacional Comum Curricular. Proposta preliminar. Segunda versão revista. Brasília. Available in: <http://basenacionalcomum.mec.gov.br/documentos/bncc-2versao.revista.pdf>. Access 04 jun. 2017.
[3] Sasseron L H 2014 e-aulas da USP: O ensino por Investigação. Fundamentos Teórico-Metodológicos para o Ensino de Ciências: a Sala de Aula. Available in: http://eaulas.usp.br/portal/course.action?course=442

[4] Biaca C A B 2012 A prática investigativa como recurso didático no ensino de Ciências. Afipa, vol.2 Paraná Brasil. Available in: http://www.diaadiaeducacao.pr.gov.br/portals/cadernospde/producoes_pde/2012/2012_fafipa_cien_pdp_cleide_aparecida_bocchi_biaca.pdf>. Access in 17 jun 2017.

[5] Meiriêi P 1998 Apprendre... oui, mais comment ? Annexe 1 : Guide méthodologique pour l’élaboration d'une situation-problème. Paris: ESF.

[6] Fabre M 1999 Situations-problèmes et savoirs scolaires. Paris. Presses universitaires de France.

[7] Robardet G 2001 Quelle démarche expérimentale en classe de physique? Notion de situation-problème. Bulletin de l’Union de Physiciens 836, pp. 1173-1190.

[8] De Vecchi G and Carmona M N 2002 Faire vivre de véritables situations-problèmes. Paris: Hachette.

[9] De Vecchi G 2004 Une banque de situations-problèmes tous niveaux. Paris: Hachette. 2004.

[10] Boilevin J M 2005 Enseigner la physique par situation-problème ou par problème ouvert. Aster (Paris. En Ligne), Institut national de recherche pédagogique, pp.13-39. ⟨hal-01066514⟩

[11] Orange C 2006 Problématisation, savoirs et apprentissages en sciences. In: M. Fabre, & E. Vellas (Orgs.), Situations de formation et problématisation. Bruxellas: De Boeck.

[12] Bardin L 2011 Analyse de Conteúdo São Paulo: Ed. 70.

[13] Carvalho A M P, Vamucchi A I, Barros, M A, Gonçalves, M E R and De Rey R C 1998 Ciências no ensino fundamental. O conhecimento físico.

[14] Sasseron L H 2015 Alfabetização Científica, Ensino por investigação e argumentação: relações entre ciências da natureza e escola. Revista Ensaio vol. 17 (ed. especial), pp. 49-67. DOI - http://dx.doi.org/10.1590/1983-2117201517s04.