A DIALOGICAL AND CONVINCING APPROACH FOR THE TEACHING OF THE GALILEAN RELATIVITY OF MOTION: FROM TRANSPARENCIES TO VIDEO AND MULTIMEDIA RESOURCES

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Abstract
This paper presents an approach, and also specific activities and multimedia resources for the teaching-learning of the topic of Galilean Relativity of the Motion, which is mainly inspired by the Dialogues of Galileo Galilei, but also taking account of results of researches on students’ science conceptions related this topic, our experience in teaching this topic and a dialogical perspective on teaching and learning which considers that the construction of scientific knowledge has to come from the students' conceptions and arguments. The approach and activities has been applied to Initial Training Teachers of Primary Education, but they can be useful in other educational levels.

1. Background and proposal
In the context of science education today, we consider that students arrive to the school with a background of knowledge which for them is undoubtedly valid and powerful enough to interpret the surrounding world. From research on students’ conceptions in science, we know that part of this knowledge is in conflict with scientific knowledge and some students are reluctant to reconsider what they think they know. As Millar (1989) and Osborne (1998) say, teachers have to persuade pupils of the value of this new way of seeing the world; to quote Ogborn (1996), teachers have to create a need for knowledge in the pupils (creating differences) that dispose them positively to the new knowledge and at the end they accept this. We agree with the perspective that considers that the teaching has to come from the students’ ideas and conceptions and also from their own way to argue; but as students cannot discover the scientific way of seeing the world on their own, we have to bring it to them, in other words, we have to present to them this new way of looking at the world (Guidoni, 1990).
If the learning involves many changes in the knowledge of the pupils (Leach and Scott, 1995; Ogborn, 1996), the teaching has to be sensitive to the need to guide these changes, and key episodes in the development of science can provide useful tools and appropriated approaches for the teaching, as for example, the Dialogues on the Great Systems of the World of Galileo.
This paper presents an approach, and also specific activities and multimodal resources for the teaching-learning the topic of Galilean Relativity of the Motion, which are mainly inspired by or are resonant with the Dialogues of Galileo, but also taking account of results of researches on students’ science conceptions related to this topic, and our teaching experience.

2. Students’ difficulties in the comprehension of Galilean Relativity
Coming from a previous study of the students’ difficulties in the Comprehension of Galilean Relativity (Castells, 1997) and from other researches on students’ ideas and reasoning related to this topic (Saltiel, 1980; Ramadas et al., 1996), we identified the main difficulties students have related to the Relativity of Motion. We summarize here some of these difficulties:
• Students don’t think that the ground and the objects fixed to the ground can move; they consider their possible motions not real, but only apparent motions.
• To describe a motion, students use objects that determinate frames of reference, but they do this without be aware of the frame, and often they mix several frames in their reasoning. The ground is the most common frame of reference. It is the natural frame of reference in many situations.
Some times other frames of reference can be used (train, ship, carrying belt, a walking man,...) because the motions happens inside, on, or in front of those objects.

- Students easily appreciate that when a body is carried by a carrying body that moves (in relation to the ground); it has the same motion of this carrying body (it participates of this motion). But, when this body loses the physics contact with the carrying body (or is outside his borders), it loses also that shared motion (velocity).

- Students find difficult to accept that two different references are possible to describe one motion. Situations with dragging favourites the possibility to distinguish between different velocities relate to different frames of reference with relative motion. But students, in fact don’t reason in terms of relativity of velocity, but with composition of motions.

- Students find difficult to accept that trajectories that are different (i.e. rectilinear and parabolic) “seen” from two different reference frames correspond to the same motion and can last the same time to be run between the same places.

- Student often confuses run distance by an object, with distance between two objects (in motion) measured in a specific instant of time or instantaneous distance.

Taking in consideration these difficulties, we design a teaching approach with several activities. At first, we select fragments in the Dialogues that are related with students’ difficulties of learning or because of the ‘problem of Physics’ considered in the Dialogues is interesting; because the ‘common sense reasoning’ the fragment includes could be shared by our students or by common people; or because there is an ‘interesting argumentation’ in the fragment to defence the ‘new idea’ which could be used by the teacher to convince students of the scientific ideas. On the base of the selected fragments we build some activities that include different multimodal resources.

3. Approaches, activities and resources

3.1. Approaches for the construction of the scientific conceptions of the relativity of motion and the frame of reference notion.

In teaching the relativity of motion, we know that motion as a change of position with respect to a Frame of Reference (FR) and the concept of the FR itself are fundamental notions. But research and our experience as teachers say us that the FR concept is very abstract and difficult to understand for the students, especially at Primary and compulsory Secondary education. So, we choose to introduce an approach to this concept based on the Bruno’s and Galileo notion of Mechanical System (MS) (Tonnelat, 1973), which is more concrete and thus more accessible to our students.

In La Cena della Ceneri (1584) Giordano Bruno presents this notion of MS as an ensemble of animate bodies with the same motion related to same reference. A characteristic of this MS is that it is impossible to recognize the motion of this MS from the experiments performed inside it.

In this approach, we at first introduce the motion as a change of position respect to a specific object and after that we introduce the notion of MS that is a concretion of an abstract FR to construct the main ideas about the Galilean relativity of motion.

With Primary Teacher Training Students (and it can be done at secondary school) we complete the FR notion of Galileo with the one of Einstein, mainly based on some texts that illustrate very well the Physics’ notion of FR (Jammer, 1970; Einstein, 1970) which considers the idea of Object-Space as a space linked to an object of reference and which we have to think as constituted by infinite points that goes out from the object in all directions and that, it is unlimited; it moves as the object of reference. To describe motions it is necessary to consider also the time, and we can imagine this space with a clock in every point. This notion of FR is more abstract that the one of Galileo but much appropriated to better understand some problems of relativity of motion. Related to this conception, we have the Einstein notion of Event (event is something that happens in a
particular point of a space in a particular instant of time), which will be used in our teaching proposal also.

3.2. Activities and multimodal resources for the teaching of the Relativity of Motion

1. Initial written qualitative problems are proposed to students as exploration of the conceptions of students:

<table>
<thead>
<tr>
<th>Imagine that you are floating with a tyre in the middle of a river and not swimming. Some up river metres there is a box of wood that floats and some river down metres there is another box.</th>
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<tr>
<td>a) If you are floating without to swim, the distance between you and each box will change with the time? Why?</td>
</tr>
<tr>
<td>b) You can suppose the tyre let the air out. To which of the two boxes would you go to arrive before? Why?</td>
</tr>
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Students solve this problem individually and after discuss in small group. We discuss with the class the several solutions students give and their arguments. Especially related to the second question, students give several solutions but their arguments are in many cases based on their intuition only. Teachers then can illustrate the “correct” solution using the resources of transparencies. The transparency resource consists on drawing a transparency for each possible FR. In the part a) of this example, we elaborate one transparency for the FR defined by the land and another transparency for the FR determined by the water of the river. In general, the transparencies are built identifying the objects that don’t move the ones relative to the others and so, constitute a MS (according the conception of Bruno & Galileo). For example, the transparency FR Land has the banks of the river and other elements of the landscape; the transparency river or Water FR includes the water, the boxes and the man with the tyre. Putting one transparency on the others and moving one or another, we will be able to see a FR which moves relative to another and that the motion of the objects changes related to one or another FR. This activity is very useful to motivate the introduction of the scientific concept of Motion and of FR. In fact, the transparency resource is a cheap and effective resource to construct the concept of FR from the one of MS. It is a very good resource because makes “real” the “apparent motion” of the bush or of the banks relative to the water. In part b) it will be necessary to introduce another transparency that has only the man. With this resource, students can appreciate and accept the scientific solution of the problem, especially of the part b), which is more difficult to them. The transparency has the advantage that it is a very adaptable resource to any specific situation or problem; we can use this resource depicting different everyday situations on the transparent plastic.

2. A very useful resource to understand and solve some problems on relativity of the motion is the resource of the diagram of events inspired in the concept of event (position -time) of Einstein. This resource can be used in the classroom in a more concrete or more abstract way, depending of the students’ level. We present here the use of this technique for the part b) of the above problem 1 relative to water’s reference frame
3. We can proportionate more experiences of “seeing” motion from several FR with the resource of video. Our videos have been recorded in our laboratory. We have several videos, i.e., a man that is walking in the laboratory and let fall out a ball or a running train that shut a ball vertically up.
or the body on which or behind which the motion takes place and they don’t consider other possible references in many situations. In our videos we record a motion that has at the back some specific bodies (walls of the laboratory, the door, …), and so they makes students “see” the motion in a natural way relative to one or another FR and so, we evidence that several FR are possible to relate the motions and that the motions change when the FR changes.

**Fig. 3.2. Trajectory of the ball falling down from a walking man “seen” from the Laboratory FR**

4. Activities reinforcing the concept of the relativity of the trajectories to the FR using the **resource of sheets of white and carbon paper**. In another text from Galileo's *Dialogues* that we recommend to our students as a reading text inspired some experimental activities in which the trajectories are evidence of motion and, so, relative to the FR. This text is the following: *The second Day: Sagredo's striking example of the ineffectiveness of motion in common* (pp. 171-172) (Galileo's *Dialogues*).

**Fig.4.1 Recording trajectories using white and carbon sheets.**  **Fig.4.2 The trajectory of ball relative to the train and relative to the ground**

Like Galileo, we use analogies, asking the students to think of a rolling a ball on the surface of a wagon of a train (or on a conveyor belt or any vehicle with uniform motion relative to ground). If the ball rolls perpendicular to the direction of the train, we can ask, for example, what will be the ball's trajectory with respect to the train? And, what will it be with respect to the station (the land)? To find the correct answer, we propose an experimental arrangement, analogous to the described situation, using the resources of sheets of carbon and white paper. We can use two woods to represent the FR Train and the FR Ground. As we can see in the Fig. 4.1, the frame Train (the wood) moves with the sheet of paper, and if the ball rolls on the wood, a trajectory will be marked on the white paper of the FR Train and on the FR Ground (wood at rest relative to the laboratory table), for example. The marked trajectories in the sheets will be analogous to the ball's trajectory in the train FR and in the Ground or station FR. Obtaining two different trajectories helps students
change their thinking about motion. We can also use one frame of pasteboard with the sheets (carbon sheet on white one) that can move on the other sheets fixed on the laboratory table. With this second arrangement, the two FR are in the same “space” (one on the other), and so, it would be a more convincing arrangement to discuss about the motion of a ball into the train “seen” from the FR Ground, for example.

5. Also, we want to refer to the resource of a cartoon we have used to discuss with students about the relativity of the velocities in a quantitative way.

You have a cartoon from one of the comics of Tintin. Discuss from the Physics point of view of Physics what happens in the history.

6. We can complement these activities proposing other problems presented as written texts included in some fragments of the Dialogues of Galileo, or inspired in another fragments, to reinforce the above commented notions. The written texts can be accompanied with simple experiments that illustrate the problems, the ideas or the supposed experiments presented by Galileo. The texts are discussed in the classes, and then a resonant, similar or analogue experiment is carried out by students or the teacher.

7. Finally, we can say something about a resource of nowadays, the applets of simulation, they are a type of resource that can have a didactical function similar to other above presented resources, but this new resource acquires the main sense if previously we have work in the classes with the other resources (transparencies, event diagrams…). It has some advantages but

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1 We have used the applets of simulations of motion from Fu-Kwun Hwang, 2008; Virtual Physics laboratory (NTNUJAVA), Dept. of Physics, National Taiwan Normal University. The author is member of CoLoS (Conceptual Learning of Science) Group http://colos.org/
also some disadvantages in comparison to the other resources. Among others, the apple of simulation of motions has the advantage that with it we can work with quantitative values and calculations in a quick way, but the disadvantage that it is only useful for the situation for which it has been designed.

4. Discussion and Conclusions
The Dialogues from Galileo are a very rich source to proportionate new approaches for science education and also specific ideas for the design of problems and other activities oriented to teach the Galilean Relativity of Motion in a way that will fit very well with the common ways of reasoning of students, these problems and activities can be adapted using simple and cheap resources as simple experiments, texts for reading, transparencies or drawing event diagrams, or other nowadays resources, as video recording or computer simulations. Researches done says us that the topic is not easy, students have to change their own way to see the world to new ways that are against the common ways of reasoning, this can’t be never easy, it is more an issue of persuasion than of discovering. And teachers have an essential role to convince students, the new multimedia resources can be useful, but without an adequate orientation and scaffolding by the teacher, the convincement of the new ideas will be quite impossible.

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