GUIDELINES IN THE DESIGN OF A TEACHING-LEARNING SEQUENCE ABOUT PARABOLIC MOTION FROM AN HISTORICAL PERSPECTIVE

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ABSTRACT

The study of parabolic motion is important because it often constitutes the prelude to the study of two dimensional physics. By studying parabolic motion, high school students are likely to develop a better understanding of vectors and their components used by physicists to study the natural world. However, students have difficulties in understanding motion in two dimensions mainly because of their misconceptions about this kind of motion as well as the way it is taught in laboratory. Therefore, the aim of our research is to provide guidelines, from an historical perspective, to help teachers designing teaching-learning sequences about parabolic motion.

Keywords: *Parabolic motion, Teaching-learning sequence, Historical approach, High school teaching, Video-based laboratory*

INTRODUCTION

Among the physical phenomena studied in high school, learning parabolic motion is important for several reasons: 1) mastery of two-dimensional concepts is a prerequisite for learning subsequent physical vector concepts; 2) the study of parabolic motion requires that the student learns new methods, such as how to separate motion in their components, to construct and use Cartesian graphs, and to measure and calculate in a systematic way various kinematic quantities such as displacement, speed and acceleration in two dimensions, which will useful in physics problem solving. Now, if there is one area that causes many difficulties for students is parabolic motion (Knight, 2004). There are several reasons for this. First, due to the complex nature of parabolic motion, students experience difficulty to distinguish and combine key principles and concepts learned in one dimension to understand properties of motion in two dimensions. Consider, for example, objects launched by firing or dropped from a moving carrier. In the first case, such as when a ball is given a horizontal speed while approaching a cliff, students think that the ball will travel horizontally for some time after going over the edge of the cliff before it begins to fall. In the second case, the belief that an object carried along possess no impetus and that upon release, will fall vertically, is shared by an important proportion of students (Dilbert, Karaman & Duzgun, 2009). These last authors could explain these misconceptions and others about parabolic motion by what they call a naïve theory of motion which is strikingly similar to the medieval theory of impetus.

A second reason of the difficulty about parabolic motion study concerns the way it is taught in introductory physics course. Indeed, parabolic motion is often dealt with a focus on mathematical quantities and formulas with which students are not used to. For example, a common educational strategy is to get the students at the beginning of the study of parabolic motion in the laboratory where they measure different properties of motion which they use to construct graphs. Back in class, they analyze their results and perform calculations using formulas in one and two dimensions for the values of displacement, speed and acceleration. Now it seems that students perform these various operations without a real understanding of what they do (Trempe, 1989). However, a hint about how to proceed to explain our students the subtleties of the parabolic motion had already been proposed to us by Renaissance physicist Galileo Galilei (Crowe, 2007). Instead of studying the parabolic motion as a whole as would have done his contemporaries, Galileo proceeded to separate the projectile motion into its main components the constant speed horizontal motion and the free fall motion. One must conclude then that the horizontal and vertical components of motion are independent and that the trajectory of a projectile thrown at a specific speed, is the combination of these two simpler motions (Knight, 2004). However, until recently, these cases about parabolic motion were the subject of demonstrations or cookbook laboratories since they require the use of complex equipment and lengthy calculations of speed and acceleration in two coordinates. In this regard, the use of technology would make easier the data collecting and analysis while supporting the student in his investigation. In this approach, called 'video-based laboratory' or VBL, the parabolic motion of objects are recorded as videos, treated by software allowing the measurement of the horizontal and vertical positions of objects according to time, while these objects undergo various parabolic trajectories, and the organization of these data in tables and graphs (Jonassen, Strober, & Gottdenker, 2005).

Indeed, the conceptual and methodological challenges encountered by students are not unlike those faced by scientists throughout the course of history in the development of new scientific theories about projectile motion. With respect to conceptual challenges, the similarities between students' conceptions and those expressed by scientists in different periods suggests that history of science can tell us a lot about the conceptual development of our students. Thus, an historical approach to science education can facilitate the development of scientific competences targeted by high school physics programs. With respect to methodological challenges, a historical approach could be used to promote the acquisition of scientific investigation skills among students. For example, in the study of projectiles, an adaptation of the original experience of Galilee (conducted in 1609) would allow students to compare their results to those obtained by the distinguished scientist, and so discuss the relative merits of experimental methods (Drake, 1989; Borghi From Ambrosis, Lamberti and Mascheretti, 2005). Moreover, an historical approach would allow the student to situate science development process within different historical and cultural perspectives (Monk & Osborne, 1997).

Despite these advantages, there are several barriers to the use of the history of science for educational purposes. These barriers include time constraints associated with the requirement to complete high school science programs and the difficulty of finding quality historical resources. In addition, some students may find it difficult to understand the point of view of historical figures. For example, students can view these characters (especially those whose theories were replaced by more modern ones) as inferior when compared to modern scientists. Consequently, our research aims to design a teaching-learning sequence from an historical perspective that takes into account the alternative conceptions of students on parabolic motion and allow them to verify their hypothesis in a video-based laboratory.

HISTORICAL APPROACH IN TEACHING AND LEARNING PARABOLIC MOTION

In order to achieve our aim, the historical approach propose here must be situated within the scope of a constructivist perspective, that is the construction of scientific knowledge must be made an explicit part of the educational process (Monk and Osborne, 1997). Indeed, it is only by overcoming the obstacles posed by the use of their misconceptions that students can develop a deeper understanding of scientific phenomena of motion and the nature of science. Therefore, it is important that students can reflect and share their knowledge about the parabolic motion phenomena under study. In addition, the development of conceptual understanding of students should be done in parallel rather than being confused with the historical development of the kinematic concept, as parabolic motion (Eckstein, 1997). In this regards, previous conceptions of students are more in a pre-paradigmatic thinking than past scientists. In this regard, one can point out that students are surely not as tenacious nor systematic in their queries regarding the natural world as scientists.

These considerations provide two additional reasons for science teachers to include the history of science. First, the historical approach facilitates the expression and discussion of misconceptions students by making them worthy of consideration in their eyes. Indeed, in this approach, it is easier for students to accept the erroneous nature of their conceptions if they can find similarities with those of scientists from different eras. Second, by discussing the historical development of a scientific concept, students are in a better position to recognize both the inadequacy of their previous understanding as well as the improvement that constitute the current scientific conception. By incorporating constructivist principles to an historical approach on parabolic motion, we propose following approach consisting of six steps (Monk & Osborne, 1997):

1) During the first phase, the *Presentation*, the teacher presents to students diverse phenomena of parabolic motion and invites them to make individually predictions about their behavior. As regards parabolic motion, we conceived two activities to study different aspects of the vector nature of this type of motion. The first case studied intends to have students focus on what happened when they compare the X component of constant speed motion with parabolic motion. The second case asks students to compare the Y component of motion of a ball in free fall and in parabolic motion.
2) In the second phase, the *Expression*, students are invited in small groups to share their own ideas and theories about the two phenomena studied in the first phase to provide multiple perspectives on their properties and how it could be explained in an atmosphere of respect and hospitality (Trudel, 2005).
3) During the third phase, *the Historical Study*, the teacher introduces richly contextualized examples including, for example, first ideas expressed on parabolic motion by Galileo (Drake, 1989; Crowe, 2007), the social and economic context of the time, various theories issued by scientists (Gal & Chen-Morris, 2013), some facts known to support either interpretation (Meli, 2006). In this phase, students are thus encouraged to consider the multiplicity of possible perspectives in the study of parabolic motion to better understand the circumstances and reasons for support for a theory over another. The information can come from various sources: historical films, vignettes, reproduction of historical instruments, computer simulation of historical experiences (Bevilacqua, Bonera, Borghi, Ambrosis & Massara, 1990; Borghi & al., 2005).
4) In fourth phase, the *Experimentation*, the teacher invites students to work in small groups to design experimental tests to determine which of the views expressed, contemporary or historical, is "correct". Given the time constraints and the variety of the ideas, it is preferable that the steps of collecting and analyzing data are made using software for collecting and analyzing data (Trudel & Métioui, 2010).
5) The fifth phase, the *Scientific Explanation*, allows the teacher to present the modern version of the parabolic phenomena studied. This version can then be compared to different hypotheses formulated by scientists of the past and ideas from students. The scientific version should be presented as one possible explanation among all the ideas expressed.
6) In the sixth and final phase, the *Review and Assessment*, students work in small groups to compare the pros and cons of each of the ideas expressed and realize that if scientific version explains the various properties parabolic motion satisfactorily, other views have also merit. Thus, students learn to use scientific assessment criteria to judge the value of an idea or theory (Reif & Larkin, 1991).

DISCUSSION

We have seen that an historical approach is particularly appropriate to facilitate learning of the parabolic motion among our students. Indeed, the projectile concepts have developed over a long period of time benefiting from the contribution of several generations of scientists (Drake, 1989; Crowe, 2007). It is therefore easy for the teacher to emphasize the temporary nature of the ideas expressed on the subject over time, while stressing that most of them constituted progress in their time. In this regard, a historical approach would allow students to better understand how scientific ideas are accepted or rejected based on empirical evidence and how controversy may arise concerning the interpretation of this evidence. These considerations regarding the study of the parabolic motion from an historical approach leads us to propose the following guidelines to design a scientific activity within an historical perspective:

1) The activity must demonstrate the complexity of the development of parabolic motion concepts and the interactions among members of the scientific community to develop a better understanding of two dimensional motions.

2) The activity must be related to the current kinematics curriculum framework for making science teachers willing to use it. In this regard, the activity should aim to make the connection between scientific knowledge (products) and processes (methods) that gave rise to them (Monk & Osborne, 1997).

3) The activity must be consistent with the current teaching practices in kinematics to meet their needs by including the history of science in their teaching while stressing its complementary nature highlighting the social, cultural and epistemological the construction of scientific knowledge (Legendre, 1994).

4) The activity should describe the authentic work of scientists in the context of the development of science (Van Driel, De Vos & Verloop, 2006).

5) Teachers should be sensitive to deficiencies of students in relation to the historical perspective of the development of knowledge about motion.

CONCLUSION

The difficulties that students meet in learning parabolic motion show similarities to those encountered by scientists from different eras. Despite the similarities observed between students' approaches and those of scientists, there are several differences so that a historical approach is not intended to simply replicate scientists' ways of thinking. Indeed, unlike scientists, students' conceptions developed often unconsciously, in interactions with everyday objects, and in a private way such that there has been few debate in classroom physics that would allow students to assess their merits. It is therefore important that an historical approach incorporates constructivist principles where students have the opportunity to express their ideas, discuss the merits with their peers, to learn about the ideas expressed by scientists at different times, check them with experiences, supported by data collecting and analysis software, and evaluate them according to scientific criteria.

Thus, an historical approach to parabolic motion would allow students to better understand how the various theories about parabolic motion have been proposed, what arguments have been brought, what empirical or factual evidence have been made in support of or against each of these theories. Not only students can compare their ideas with those of distinguished scholars, but they can also better realize the transient nature of the different theories, while situating the development of science in a social and cultural perspective.

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