A short film (and CD-ROM) on the controversial notion of the concept of force

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Abstract: *The present work is the result of a project (SPEC/PROIN-CAPES) for making short videos (and CD-ROMs) for the teaching of physics in high schools and colleges. The video tells the history of the concept of force from the notion of Aristotles antiperistasis, the notions of acquired impetus of Philopponus, Oresme and Buridan to the dynamic notion developed by Newton. The subject was developed and based on the students alternative conceptions related to the phenomenology of mechanics.*

Key words: *physics teaching, history of science, alternative conceptions, verbo-visual language*

Resumo: *O presente trabalho é o resultado de um projeto (SPEC/PROIN- CAPES) para a realização de vídeos (e CD-ROMs) de curta-metragem para o ensino de Física no Ensino Médio e Superior. O vídeo conta a história do conceito de força da noção aristotélica de* antipresistase*, às noções de* impetus *adquirido de Philopponus, Oresme e Buridan, até a noção dinâmica desenvolvida por Newton. O enredo foi desenvolvido e baseado sobre as concepções alternativas relacionadas à fenomenologia da Mecânica.*

Palavras-chave: *ensino de Física, história da Ciência, concepções alternativas, linguagem verbo-visual*

1 Introduction

The aim of this work is to present a short-duration film (a 15-minute video) to introduce the controversial notion of the concept of force throughout the history of physics. This film is part of two projects and a program of tutorial education, developed at the Department of Physics of the State University of Maringá: Project LCV (Laboratory of Visual Creation), Project PROIN (Interactive Program between Graduate and Post-Graduate courses of Physics) and Special Training Program or Tutorial Education Program (PET). These projects and program aim at developing activities to improve the undergraduate course of physics and to develop didactic tools directed to teachers-in-service programs (high school teachers).

Each year we make a standard test to undergraduate students concerning their qualitative knowledge on the physical phenomenology and scientific culture. The results are valuable in the sense that they help us to program certain activities directed towards theoretical classes or laboratory activities. It is important to point out that the results of the applied standard test delineate patterns of answers like alternative conceptions. In many cases, these conceptions recapitulate the history of the science in pre-Newtonian models resulting from an explanation based on a construction of the visible world founded upon a dissipative physical phenomenology (friction, drag forces, etc.).

The test and its results will be presented in the section below. Further, the contents of the video produced will be given, justifying the choice of subjects related to the conception of forces and the open questions on this conception even in 21st century Physics.

2 Alternative conceptions and the video

Researches on students' ideas, initiated already 20 years ago (ZAROUR, 1975; VIENNOT, 1979), currently constitute a watershed in research on Physics/Science teaching. When the first article was published (ZAROUR, 1975) on the mistaken concepts (misconceptions) of the students, there was no theory about the students ideas (in the sense of knowledge outlines). Teaching was thought as a communication of knowledge to a tabula rasa. This kind of educational approach fails when students mistakes are held to be a synonym for students stupidity. Behaviorism suggested a teaching based on scientific methods (credited, in their majority, to the modus operandi of Galileo Galilei). Scientists interested in the transmission of the knowledge and in the epistemological and psychological problems of the development of the knowledge, had developed hypotheses on the nature of a common knowledge (BRONOWSKI, 1985) and pointed out the importance in contemplating on the students mistakes (ALBANESE *et al.*). However, an empiric reference still did not exist to attribute a scientific validity to such hypotheses. After Viennots work bringing the results of a research on spontaneous reasoning in elementary dynamics, specialists found a very rich research vein by which the style of the questions made to students stimulated the explicitation of answers of a non- standardized kind schemes (different from the notions commonly accept for the theories and effective models).

Therefore a research boom was born in several parts of the world. Its methodology consisted of question tests to obtain interesting data (questionnaires of paper and pen with open answers or of multiple subjects; clinical interviews; Piagetian-like clinics).

Certain empiric data were established from this research that presented two very important characteristics:

i) cultural non-variance (students of several countries answered in the same way, or almost, the questions presented);

ii) substantial independence of answers for the type of received teaching.

With these characteristics in mind, there was a great need in seeking an explanation for the empiric data collected in a theoretical reference that would account for cultural non-variance and, at the same time, for independence in relation to the found answers. Hypotheses on a science of common sense acquired a scientific meaning since it prefigured a model of learning as a constructivist way. Anyway, in teaching, the empiric data mark the passage from a pre-paradigmatic phase to a paradigmatic phase. This may be noticed by the substitution of the word misconception (similar to the wrong concept). It denotes the falsehood of such ideas with regard to scientific knowledge in the case of words that do not express knowledge in terms of scientific knowledge but as alternative knowledge (naive physics, spontaneous physics, alternative conceptions, mental representations), founded on a constructivist hypothesis of knowledge. We will not enter in the debate between behaviorism versus constructivism. We will just show the results of a questionnaire involving undergraduate students with regard to mechanics. It will show the need of didactic tools, such as a short video on the history of physics and the open questions about the nature of physical notion of force.

An open questionnaire involving questions, described in the tablebelow, was used to map alternative conceptions in mechanics.

Results show a great percentage of alternative conceptions ranging between 30% (question 2) to 90% (question 5). Results also confirm other similar situations obtained around the world. The maintenance of a high percentage of alternative conceptions, especially by students of an undergraduate course, is worrying. This situation puts in evidence a teaching without challenges and situations of cognitive conflicts. Science is taught through the boring linearity of facts, events and theories (taken as the ultimate reality of Nature).

These results stimulated the authors to produce a short video about the important conception of force. It put students and teachers in contact with their own alternative conceptions and with the rich history of physics.

The videofilm was produced to fit some difficulties that students and teachers may have on the themes linked with mechanics. This is specially true with regard to the long history of the notion of force and the open questions on the nature of the unknown concepts (Mach, Assis and Milgrom models about the non-existence of inertial forces).

1) Suppose a tunnel that perforates the whole Earth (illustrated in the questionnaire in three situations: (*a*) vertical; (*b*) inclined; (*c*) horizontal). According to your opinion, what would happen to a stone abandoned at the opening of each one of the tunnels in each one of the three situations? Justify your answer.
2) Let's suppose a cannon shot. In the three moments of the trajectory (at the start of shot, in the middle of the trajectory and on the arrival point), what are the forces involved? Draw these forces.
3) According to your opinion, why does a stone continue moving after leaving the hand that threw it?
4) Imagine a balloon put at the bottom of the sea. According to your opinion, what would happen to the volume of the balloon? Justify your answer.
5) Why do astronauts float inside a spaceship?
6) What happens with the measurement of the registered weight of a stone put on a plate of a lever when the whole system is placed in a vacuum box?

Results obtained in the questionnaire have been hardly considered. The difficulties presented and the emerging alternative conceptions were used as the motus of the videofilms screenplay. The following six figures summarize the content of the video (and CD-ROM) produced.

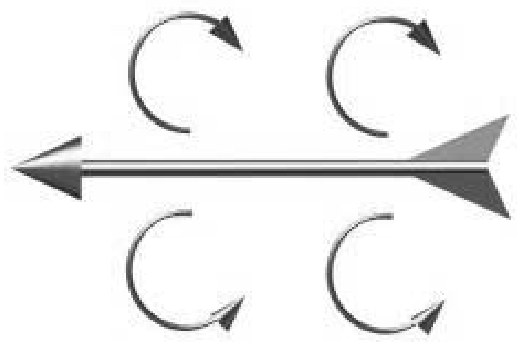

Fig. 1. Antiperistasis (an arrow moved with the aid of air - external motor).

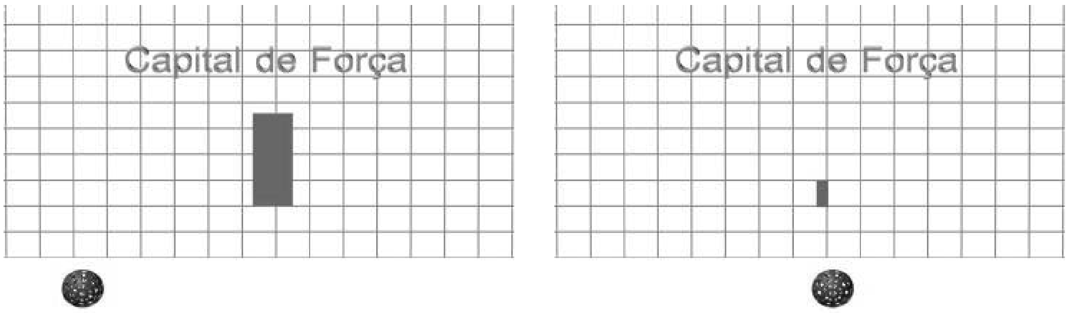

Fig. 2. Capital force (impressed force, like an impetus)

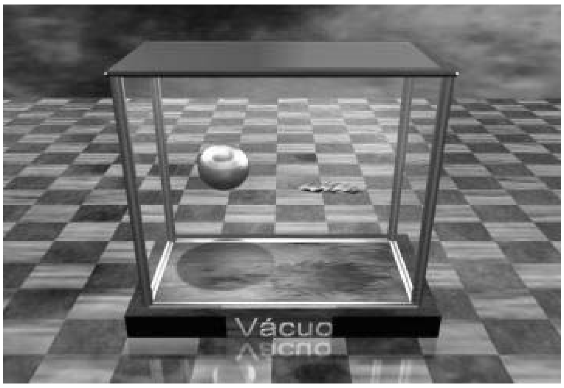

Fig. 3. A virtual experiment: a heavy ball and a light plume falling at the same time in a void (Galileo's gedankenexperiment).

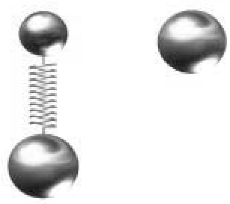

Fig. 4. Another Galileo´s gedankenexperiment to discredit the Aristotelian concept of "velocity proportional to weight": a light ball linked to a heavy one would fall either faster or slower than a ball in a free fall.

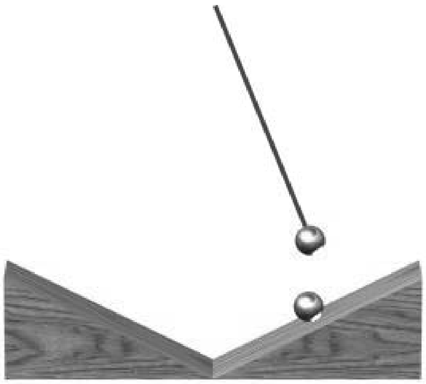

Fig. 5. The "equivalence" between pendulum and the motion of a ball on two inclined planes.

Fig. 6 - Newton´s gedankenexperiment: the bucket.

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