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Teaching Dynamics with the Historical Method: The Pre-Classical Approaches and the Newtonian Principles within the Content of Physics

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Abstract: The following work introduces an innovative methodological approach for the teaching of the Dynamics in the curriculum of the lower secondary education. The approach takes in account the difficulties which have been traced among the pupils as they deal with the newtonian law of the motion in high school classes: Though pupils have been born and grown up within the newtonian principles, it seems that they comprehend the natural phenomena in a non –newtonian way. On the other hand, pupils cannot link effectively the content of Physics with the every-day life. Nielsen & Thomsen have outlined these difficulties among the Danish pupils (but this is something common that we all face in our schools) indicating that "the majority of secondary school students find Physics to be difficult, unrelated to other schools subjects and with very little connection to real life.

Key words: Newtonian, physics, historical method, dynamics, teaching physics, history of science and didactics, Aristotelian Natural Philosophy, Aristotle, Philoponus, Newton

1. Introduction

Michael Matthews, being an enthousiastic supporter of the use of History in Physics teaching, has focused intensively on the benefits which can be brought out from the use of History of Physics in Physics teaching (Matthews M.,1994). This method has been worked out by several researchers in the last decades. A very informative review for the use of History of Physics in Physics teaching has been presented by Seroglou & Koumaras (Seroglou F. & Koumaras P., 2001). Lately, G.N. Vlahakis, presenting the cautious relations between History of Science and Physics extensively, has shared Matthews' views as well and he has indicated with remarkable accuracy that we have to "reintroduce physics to society" (Vlahakis G. N., 2008, p. 53).

The teaching method we propose attempts to overcome these difficulties historicizing the introduction of the laws of motion. That is, to bring out the pre-newtonian laws of motion as they were introduced and defined by natural philosophers and scholars in certain historical periods of time. So, under this scheme, we attempt to conjoin the scientific progress and achievements with the social conditions that these scholars had experienced. In other words, we propose "to familiarize pupils with the way of doing Physics, as a method of human exploration and learning about the nature", as I. Galili has pointed out (Galili I., 2008, p. 8).

We regard that the teaching procedure of the newtonian law of motion should include presentations which will lead to the clarification of the principles of the pre-classical Dynamics as well as the concepts of the pre –

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newtonian laws of motion, mainly the laws of motion that were introduced by Aristotle and John Philoponus, "a christian schooled in Neoplatonism" (circa 490s'–570s') as Richard Sorabji has mentioned (Sorabji R. (ed.), 2010, p. 41). Also, we can add and outline certain efforts undertaken during the medieval period which were trying to interpret motion. The study of these laws will certainly focus on the differences between the ancient view on natural phenomena (aristotelian or non-aristotelian) compared with the newtonian synthesis as it was introduced in the post-galilean world.

According to McGuire's views, the patterns we use to approach and interact with the natural environment change (McGuire E. J., 1999), so the two laws which were introduced in the pre-newtonian cosmos — having been set up in different periods of the scientific evolution — were based on different conceptions about the natural phenomena than the ones we accept and follow nowadays.

In particular, the aristotelian law of motion, as it was introduced by Aristotle at his *Physika* attempting to interpret the so-called violent motion of the projectiles in the sublunar part of Cosmos formulated the cornerstones of the Stagirite's approach for natural phenomena, namely the absence of vacuum space within the Cosmos, the relation between the motive force which is enforced in a motionless body and the resistance of the surrounding medium, the limitation of the motive's force duration as well as the limitation of the period of the violent motion.

Aristotle's approach was based on qualitative criteria for the interpretation of the violent motion and influenced totally by the empirical reality as it was conceptualized by him.

2. The Pre-Classical Laws of Motion

Aristotle's law of motion related the imparted motive force to a projectile proportionally with projectile's velocity and inverse proportionally with the resistance of the surrounding medium. This relation, fully functional with the principles he had introduced for natural procedures, could not lead Dynamics to the inertia as it was introduced by Newton in 17th century. Aristole's law of motion implied the non-existence of the vacuum space, as the acceptance of the existence a medium with no resistance within it would bring forth the infinite velocity of projectiles which could not been observed anywhere in Cosmos and consequently was not accepted by Aristotle. Actually, these two concepts, the absence of vacuum space and the denial of the infinite velocity, were the cornerstones of the aristotelian Natural Philosophy. For Aristotle, any motion in a void space would be an infinite motion without any inclination, without any will or task: Projectiles would not know where to go and when to stop. Thus, this motion would be infinite as well. Consequently, these principles performed as the basic obstacles for the introduction of the inertial interpretation of motion.

The introduction of the aristotelian law of motion formulated the view of the Stagirite on motion as the only systematic pre – classical method and, on the other hand, proclaimed the weak points of it which contributed to the rise of the historical questions of Dynamics from ancient era until the 17th century, like the interpretation of the acceleration during free falls and the absence of continual contact between motive forces and projectiles.

Philoponus' law of motion — as a part of his contribution to Dynamics — was formulated in Late Antiquity, a very interesting era between the twilight of the ancient period and the forthcoming medieval centuries, as we have mentioned elsewhere (Kartsonakis M., 1996, p. 70). Actually, the law of motion he proposed contained the possibility of vacuum's existence as it was derived from the christian background he had.

The view for vacuum he has accepted was based mainly on the comprehension of space he adopted.

Philoponus opined that space has to be considered as an extensible entity, regardless of the existence of material bodies within it, as Aristotle had introduced in *Physika*[1]. Under this scheme, Philoponus did not hesitate to accept the existence of vacuum, referring to it, simply, as the medium with no resistance[2].

On the other hand, he introduced an alternative interpretation for the justification of projectiles' motion, the preliminary version of the medieval impetus theory which was introduced in the 14th century in Paris University, and he held that the placement of a body in the vacuum does not imply that it will be simultaneously at two places in it. Consequently, he concluded that motions in the vacuum space have limited duration. This motion ends according to factors within projectile and the amount of impetus which has been incorporated in the projectile.

According to this, completely different from Aristotle's, view for vacuum's existence, Philoponus traced the possibility of a different law of motion with a very radical methodology: He has described a hypothetical experiment. His experiment confronts the motion of a particular projectile at a certain distance in different media, setting as starting point its motion in a vacuum space where he assumed that it will need one hour to cover a given distance. Then, he assumed that the same motion took place in water. He mentioned that in water projectile's motion would last two hours for the given distance. Then, he confronted that same motion into air which density's was half comparing of water. At that medium the projectile's motion would last one hour and a half, as he mentioned. If we replace that air with air having half density, then the duration of the projectile's motion would had been one hour and a quarter. And, he added, that if we continue reducing the density of the medium, then the duration would reduce reaching the value that had in the vacuum, but never getting this value, that is one hour, because he indicated that time is endlessly divisible[3].

At this exceptional hypothetical experiment we can trace Philoponus' insight because he adopted an abstract methodology for his methodological approach for the question of vacuum and motions within it, very early in the history. Thus, he confronted this question as a typical mathematical function where time has the role of the dependent variable and medium's resistance is the independent variable.

Following the conclusion of this theoretical approach, Philoponus concluded that motions can be interpreted by a diversified relation for motive force, medium's resistance and velocity. This alternative law of motion contained the possibility of motion in the vacuum. Following his view, projectile's velocity can be measured by motive force's impact subtracting the value of the resistance of the surrounding medium. Thus, this law of motion stands even if we consider a vehicle moves in the vacuum with zero resistance[4].

3. The Methodological Case Study

The study of the pre-classical Dynamics and the pre-newtonian laws of motion reflect the interpretation of the scientific ideas which were active during the eras the scholars had lived. So, this study can lead the pupils actually in the core of the concepts they opined for the Cosmos and the natural processes. Thus, this method can be considered as a contribution to the evolution of scientific ideas, in cognitive and in meta-cognitive dimension as Seroglou & Aduriz-Bravo have pointed out (Seroglou F. & Aduriz-Bravo A., 2007).

In particular, we consider the concepts of nature and the law of motion which was introduced by Aristotle as

[1] Aristotle, *Physica*, 212a20 -21.
[2] Philoponi, 1887-88, 557.8 – 585.4 & 675.12 – 695.8.
[3] Grant E., 1965, 85.
[4] Philoponi, i.bid., 678.24 – 684.10.

a reflection on his views on main concepts of motion within the ancient Greece's philosophy cultural environment. On the other hand, Philoponus' law of motion was introduced during Late Antiquity in Alexandria and had been based on the aspects of nature he had adopted during that era of transition, inspired by the Christian principles he has adopted though he was a neoplatonist.

So, the study of the laws of motion may contribute effectively to the study of the cultural history as well as to the study of evolution of ideas taking in account that the aspects and the conclusions derived from them represent views of the social and philosophical scene of the eras they were introduced.

4. The Research

Some of the concepts that can be enquired with the procedure we propose are: the ratio between the motive force and the projectile's velocity, the concept of inertia, the concept of heaviness versus the modern concept of weight, the acceleration during the free fall and, apparently, the question of the void space. All these questions are expected to lead to a main task of the Physics teaching: the decrease of misunderstandings about the nature of motion and the law that interprets it.

Moreover, some other expected benefits for the pupils according to this method can be traced on multiple fields. On one hand, the pupils will achieve to understand fully the Newtonian law of motion getting acquainted with the gradual shift from the Aristotelian view for nature — and consequently from the Aristotelian law of motion — towards the inertial Physics and on the other hand they will confront the concept that scientific achievements are fully incorporated within the historical evolution of the societies.

We have enquired the proposed methodological approach organizing a research which took place during the spring 2011 among pupils who have not yet been taught the classical law of motion in high school. The preliminary outcomes of this research confirmed the non-Newtonian pre-conceptions of them.

The questionnaire was given to 100 pupils, 12 years old who attend at the 1st class of High school. It is composed by 8 questions referring to Dynamics and the laws of motion. Though the sample is limited, the answers they give confirm specific difficulties pupils face for the newtonian law as a methodological approach for motion.

The first question attempts to trace the relation between motive force and its result at projectiles: Does its increase related with velocity or acceleration? 73% of the pupils answered that it is related with projectile's velocity and only 27% that it is related with its acceleration.

The second question is focused on inertia: 62.5% of the pupils replied that if no force is implied on a body it will either move with uniform velocity or remain immovable while 37.5% of them answered following the aristotelian view that it will remain immovable.

The pupils are asked at the third question of the survey about weight. Some of their answers connect the concept of weight with the amount of the mass whether the majority of them defined it using "aristotelian" phrases such as "how heavy or light the body is".

The fourth question describes an experiment, the simultaneously free fall of two equal stones, from the same height, in two different boxes, one full of honey and another one full or air. The great majority of the pupils (83.5%) answered that the stone which falls in the box with the air will fall faster. The justifications of their answers includes answers such as "the box that contains air is actually void and, consequently, it will fall faster because at the other box honey is thicker than air and it will *impede* its fall" or "it will fall faster because air is

lighter than honey and this helps the stone to fall faster". The rest pupils — incomprehensibly — answered that the stone which falls in the box with the honey it will fall faster than the one in the air!

The fifth question deals with the motion of a projectile in a box where we take out all the air and leave it void of. 31% of the pupils seem that have been inspired by the aristotelian interpretation for this issue and answered that the projectile will move with infinite velocity to the bottom of the box while 40% of them agree that the projectile will move with increasing velocity until it will reach the bottom of the box. The remaining 29% of them answered that it will not move and will remain immobile on the top of the box.

The next question compares the free fall of two bodies, a little coin and a heavy brick, in a box with vacuum. They are considered to fall down from the same height. 20.5% of the pupils answered that the coin will reach first the bottom of the box while 53% of them think that the brick will reach first the bottom of the box and only 26.5% answered that they will reach the bottom at the same moment. Some of their justifications are "the brick will fall faster because it is *heavier* than the coin", "they will reach the bottom of the box simultaneously because there is no gravity and thus the weight of each of them does not matter", "they will fall simultaneously because there is no gravity in the vacuum".

At the seventh question there are three sentences and they are asked to choose the correct one. The first sentence enquires the Aristotelian law of motion: "When a vehicle moves, its velocity is proportional to the motive force which has been incorporated into it" and was chosen by 37.7 %.

The second sentence introduces Philoponus' law of motion to them: "When a vehicle moves, its velocity is proportional to the motive force which has been incorporated into it minus the resistance of the medium where the motion takes place" was chosen by 49% of the pupils.

The third sentence which describes the newtonian law of motion "When a vehicle moves, the gradual variation of its velocity is proportional with the force which has pulled it" was chosen only by 13.3 % of them.

At the eighth question they are asked about the free fall of a stone which falls from a certain height. 33 % of the asked pupils answered that it will fall with uniform velocity while the rest 67% replied that it will fall with gradual increasing velocity. Their justifications included answers such as "it will fall with gradual increasing velocity because the centre of earth is like a magnet which attracts all bodies downwards", "its velocity will increase because as long as it falls because extra value is added during its fall", "velocity will increase because of the impetus of the air".

Briefing the above answers, we can say that the derived conclusions that are traced lay on the insufficient comprehension of the newtonian law of motion and the newtonian interpretation in general. On the other hand, it seems that the law motion which was proposed by Philoponus seems to be a more attractive interpretation for the motion among pupils.

Also, another conclusion that can be derived is that we have to clarify more accurately aspects of the classical Dynamics (the interpretation of the free fall, the gravitation as a force, the vacuum space) in order to make pupils more acquainted with them.

5. Conclusion

Summing up, we propose that History of Physics can offer a very useful and effective method for the teaching of Physics. In particular, in order to second this method, we have focused on and the newtonian law of motion as a pattern and the teaching of the historical questions of Dynamics in general, we have inquired the pre –

newtonian laws of motion and we have reached to very interesting conclusions. This method can contribute to a viewpoint which underlines that the scientific achievements have to be considered as a major part of the social and cultural environment within they have been introduced.

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