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Analysis of the conceptions of senior secondary school physics teachers in Morocco, about the inertial motion as a motion-state

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Abstract : *This article is part of didactic researches inspired by the history of science. Our aim is to identify and analyze the conceptions implemented by Moroccan physics teachers of senior secondary school, confronted with questions relatedto the perseverance of inertial motion as a motion-state, asexpressedby the principle of inertia formulated by Newton. The study was conducted among 59 teachers who responded to three multiple choice questions, guided by a research question. Pivot tables wereused when necessary, in order to establish a typology to the conceptual basis. The analysis of the results has proven that for many teachers, this new form of intelligence of this movement is not sufficiently clear, and the discontinuity with the Aristotelian notion of motion-process has not occurred.*

Keywords: *inertial motion; motion-state; Teacher; Principle of inertia; Newtonian mechanics.*

I. Context and problematic

The history of science shows that the principle of inertia has a foundational role in Newtonian mechanics, as well as its wording "represents the blockadethat had to be blown upfor the other laws of mechanics to emerge" (MEN Fr 2001, p. 3).

1.1 reference knowledge

The formulation of lawof inertial providedby Newton predict that "every corps**perseveres** in **the state** of **rest** or **uniform motion in a straight line** in which it is located, unless some **force** acts on it, and oblige it to **change its state**. " (Newton, 1686) By introducing the term "state of motion" Newton affirmsthat the motion is also a state, that is to say that it is something that does not involve more change than the rest does. The motion and rest are located by this word at the same level of being[1].

Euler (1760), detailing the concept of state, wrote in a didactic text: "As we say that a body, as well as it is in rest, remains in the same state, we also say thata body is in motion, as long as it moves with the same speed and in the same direction, it remains in the same state "(Euler, 1760, p.321). Thus, he specifies, remaining in the same state does not mean anything other than remaining at rest or keeping the same movement. It is precisely and only because it is a state - Exactly as the rest-that the movement is able to conserve[2]. And that the bodies can persevere in the motion without the need for any force to move them, exactly as they persist in the rest.

It is only the motion as a state which requires neither cause nor engine. Yet, every motion is not a state, but only the one which proceeds uniformly and which is in a straight line, that is to say in the same direction and at the same speed at any point of its trajectory in space.

In fact, for physicists the concept of state is always clear. Thus, for Lagrange, when a body persists in its state: it retains its speed and direction (in Koyré 1986, p.162, note 4) It is actually, after "the formulation of the concept of motion-state"(Meyerson, 1951, p.165), or when the movement became as a state that it manifeststhe "invincible tendency to maintain its identity within time"(Meyerson, 1951, p.160), this is also to say,to be maintained. Therefore, the reason for such "existing motion at time t_1 is that this same motion existed at time t_0" (Ben Jaballah, 2000 p.87).

[1] Kepler ranged them at different levels; he compared them to darkness and light. (Koyré , 1968 p.95)

[2] It is obvious that bodies could not keep their motion as long as it was considered as a process of change. The motion process could not continue without an engine. Nothing changes without a cause as Newton expressly stated. (Koyré , 1968 p.95)

Finally, as the motion-state concept, introduced by the principle of inertia, needs further clarificationsby physicists, followed by those of historians of ancient and contemporary Science; this suggests that understanding this concept is meeting possible difficulties.

1.2 Work of didacticians

At first, we would like to note, based on our knowledge, that there are no didactic studies specifying the concept of motion-state, as it was introduced by the principle of inertia and detailed by physicists and historians of science.

However, we will refer to the work of didacticians who touched in one way or another, the subject of research, and then we will make a detour through physics textbooks and Moroccan school programs, in order to address some observations related tothe inertial motion in its relation to the state of motion concept, as it is officially mobilized.

- In addition, the study Azzaoui et al (2014),shows that the trend of physics teachers to find a cause to the inertial motion is evident. This later is declared, sometimes as a force: either external, or "owned" by the body in motion. For others, it is an "anterior cause stored" in the moving object.
- **COPPENS**(2007) in his doctoral thesis, regarding the first law of Newton, all cited[3] results show a misconception, mobilized by the students, expressingan adhesion force -speedin different situations.
- **Grenier** (2001), in terms of teaching sequences proposed by his study, highlights that students "issued mainly the assumption that in the absence of friction, a body in uniform motion, will not stop "(Grenier, 2001, p.16).
- Our research results (Azzaoui et al, 2007), for Moroccan university students who have already completed the module mechanics of the 1st semester, show that only 15% of them conceive, according to the principle of inertia, that free body in space, is in straight uniform motion, and give a right representation showing positions of its central point, regularly spaced during 1s. This work confirms the presence of difficulties, for students, to put themselves properly in the context of principle of inertia in space. Our research end upquestioning the objectives and the teaching methods of mechanics in senior secondary school.

1.3 Some observations from school textbooks and official instructions

- ✓ We experienced neither in the official instructions nor in textbooks, any historical note concerning the formulation of the principle of inertia or its importance in Newtonian mechanics. While in Great Britain (1988), the National Curriculum Council published the study program Science in the National Curriculum which recommends incorporating a historical dimension in teaching sciences. (Science in the National Curriculum1989, p.79)
- ✓ The notion of motion state is used in the meaning of the current language, which opposes it to the state of rest, and not as a specific characteristic of the inertial motion which place it"to be at the same level" as the Rest (Koyré 1968, p.94), and distinguishes it from the Aristotelian motion-process.
- ✓ Programs and scholar textbooks do not address explicitly, the perseverance of inertial motion, neither within time nor within space. In fact, the equations of motion staysilent; they generally do not reveal these two features, at least among learners.

Therefore, regarding the concept of motion-state, our study proposes to target Moroccan teachers of physics in full exercise of their profession in senior secondary school, since each one of them is considered to be the key player in building the conceptions of physics among students. In other words, he is the first to mobilize knowledge to teach, from where the importance of defining its conceptual way in relation to our subject. To do this, our study attempts to answer the following research question:

Research Question: Could the Moroccan physics teachers, of senior secondary school, break up with the motion-process and adopt the motion-stateconception characterizing the inertial motion?

II. Research Methodology

In order to highlight the conceptions of teachers involved in this study, we chose the multiple choice questionnaire as a data collection tool.

[3] The author cites , as an example on page 22: Viennot , 1979; Clement, 1982; Gunstone , 1987; Enderstein and Sapargo , 1996 , Mildenhall and Williams 2001

2.1- The questionnaire

Our research question is operationalized by three sub-questions; A1, A2 and A3. These questions are part of a global questionnaire with complement interests,focusing on the principle of inertia. Thus, for each sub question, the respondent has the choice between "Agree" with what it offers, and "Disagree". A choice of "No answer" for to every question is an opportunity to the respondent to explicitly declare that he is not able to position himself for the lack of answer. However, if the respondent does not check any of these three choices, we take this case as "unanswered".

2.2- The sample

Our random sample consists of 59 Moroccan teachers of physics workingat senior secondary school. There are 48 males and 11 females, and their average seniority of teaching is 25 years. They have already taught the chapters of mechanics, which is spread on the programs of the three years of this cycle of education, and particularly that of the principle of inertia in different school levels, with different approaches based on the reforms of programs experienced by the physics education in Morocco.

3- Analysis of the results

From an intellectual point of view, the conception of motion-state, not using anything to persevere, is a new form of intelligence that breaks with the notion of motion-process inherited from Aristotle. Such perseverance keeps the same state of motion even though the location changes and the time vary.

Thus, our research question on this concept is framed by the following three sub questions:

In the absence of any external resistance, a body in uniform rectilinear motion:	Agree	Disagree	No answer
A1- can still continue its motion without the need of something to move it			
A2- when this body is in D, it is precisely in the same state of motion as it was when in C.			
A3- The reason that this body is, at the current time, in a straight uniform motion, is that the same motion existed at an earlier time			

Our three sub-questions / suggestions seem to focus on three dimensions of the concept of motion-state: intellectual dimension (A1), spatial dimension (A2) and temporal dimension (A3). Thus, a good answer cannotbe right without agreeingto each one of them.

The table 1 below summarizes the results of choices of teachers in our sample.

concept	**Question**	**Code**	**Choice**					
			Agree		Disagree		No answer	
			$N_{(frequency)}$	%	$N_{(frequency)}$	%	$N_{(frequency)}$	%
Motion-state	The URM perseveres without need of something to move it	A1	50	85%	4	7%	5	8%
	The URMhas the same state in D as it was in C	A2	42	71%	10	17%	7	12%
	The reason for the URM at t2 is that the same motion existed at t1 (before now)	A3	27	46%	21	36%	11	19%

Table 1

To analyze these results, we will establish pivot tables of sub-questions two by two in order to understand the tendency of teachers' responses.

3.1-Spatial-intellectual Crossing

- **Crossing 1**

			Spatial dimension (S.D)	
			A2 : The URM has the same state in D as it was in C	
			Agree	Disagree
Intellectual Dimension (I.D)	A1 : The URM perseveres without need of something to move it	Agree	Motion state having (I.D) & (S.D)	Change of state in the absence of external action
		Disagree	Proportional force with constant speed	Motion Process

The results of these four categories are grouped in Fig.1.

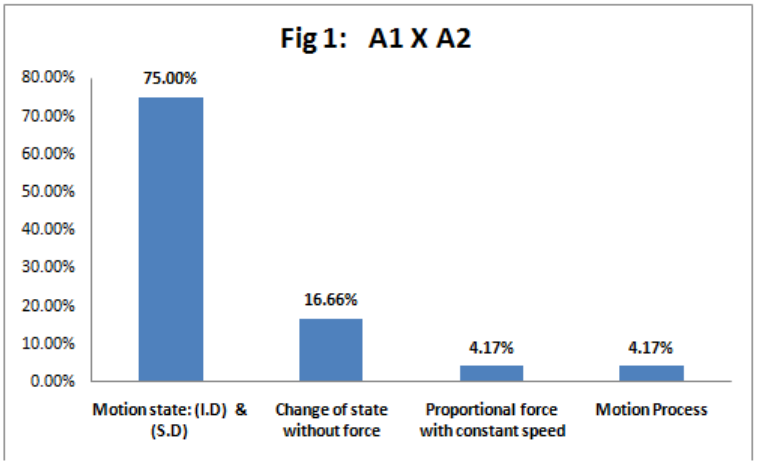

Figure 1

Analysis of results of crossing 1

The percentages of the four categories appeared during this crossing are as follows:

- 75, 00% agree with the new form of intelligence introduced by the principle of inertia: the inertial movement perseveres without the need something to move it; and that the state of this motion is the same in all points of its trajectory. These teachers recognize the two dimensions of inertial motion: the intellectual dimension and spatial dimension. - For 16.66%, a change of location is a change of state although nothing acts on the body in inertial motion. This contradicts the last part of the Newtonian statement "unless some force acts on it and forced it to change the state": thus, any change of state is conditioned by the action of force.

- 4.17% claim they agree with the fact that the state of inertial motion is conserved in all points of its path, so its speed is constant, but do not agree that it perseveres without the needof something to promote it: the necessity of a "cause" / force, for them, is explicit. It is therefore proportional to the constant speed, which contradicts the 1st and 2nd law of Newtonian mechanics.

- Finally, for 4.17%, inertial motion requires a cause to be maintained, and cannot maintain its state: these teachers still keep the notion of motion-process.

This means that 25% of teachers who do not associate the intellectual conception of the motion-state provided by the law of inertia, with the conservation of this state along all positions it holds, or even keep the Aristotelian conception of motion -process.

3.2- Crossing temporal intellectual

- **Crossing 2**

			Temporal dimension (T.D)	
			A3 : The reason for the URM at t2 is that the same motion existed at t1 (before now)	
			Agree	Disagree
Intellectual Dimension (I.D)	**A1** : The URM perseveres without the need of something to move it	Agree	Motion state having (I.D) & (T.D)	Experimental realism
		Disagree	Proportionality between "cause" and constant speed	Motion process

Four categories emerged, the results are as follows:

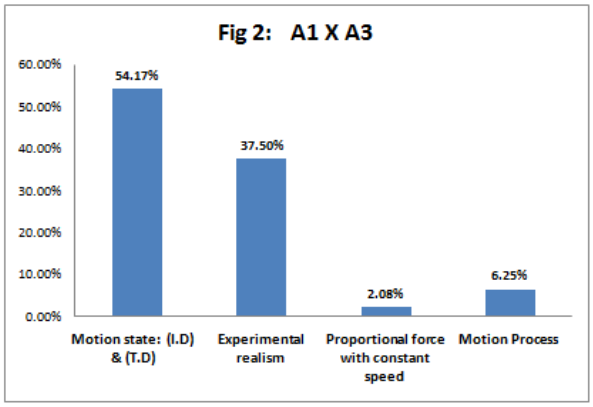

Figure 2

Analysis of results from the crossing 2

Four categories appear: - 54.17% associate the two dimensions intellectual and temporal: for them, the inertial movement perseveres without the need of something to move it; and its state remains the same at any moment.

- For 37.50%, the inertial motion does not need external action, but does not continue as a state: for them, the conservation state over time does not seem to be clear. Does these not impregnated teacherswith what we call "experimental realism", for whom the movement cannot be maintained out of the few milliseconds required for the experiment on the free standing table, limited byits nature, as they often usingit as a teaching tool.

- For 2.08%, the cause is proportional to the constant speed.

- 6.25% still keep the Aristotelian notion of motion-process.

In total, 45.83% of teachers in our sample do not associate the intellectual and temporal dimension of the motion-state. If they recognize in the inertial motionits perseverance without external action, they refuse preservation of its state at any moment and vice versa, or they even join the Aristotelian conception of motion-process.

3.3- Spatiotemporal Crossing

- **Crossing 3**

			Temporal Dimension (T.D)	
			A3 : The reason for the URM at t2 is that the same motion existed at t1 (before now)	
			Agree	Disagree
Spatial dimension (S.D)	**A2** : The URM has the same state D as it was in C	Agree	Motion state having (S.D) & (T.D)	Ambiguous conception
		Disagree	Contradiction conception	Difficulty with respect to the conservation of state

The results of this crossing are shown in Fig.3.

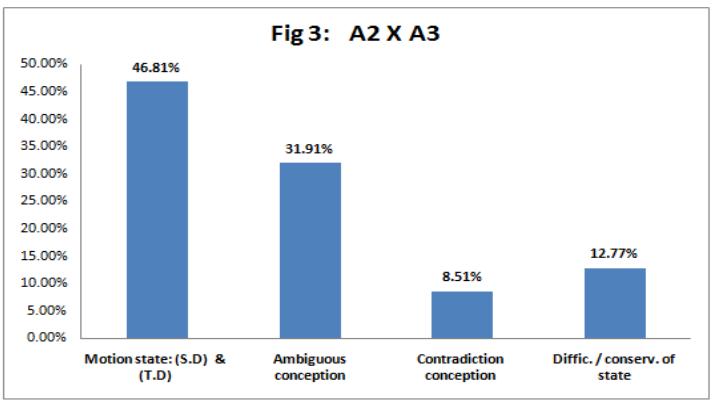

Figure 3

Analysis of results of crossing 3

- 46.81% recognize the two dimensions spatial and temporal: The state of inertial motion is preserved during the change of location and time.

- 31.91% agreed with the conservation of the state of the inertial motion at any point in its right path, but this conservation is not recognized at any time: the notion of motion state is ambiguous.

- For 8.51%, the change of location corresponds to a change of state, but this category agrees with the conservation of the motion statewithin time. These teachers have a contradiction conceptionconcerning the concept of motion-state.

- For 12.77%, there is a double rejection of the conservation of state of the inertial motion.

In total, there are 53.19% of the teachers who have difficulty to recognize the conservation of state of the inertial motion in space and / or within time.

3.4- What about the three-dimensional of motion-state?

We have performed a filtering operation, based on our data matrix, targetingthe answersof teachers in our sample who haverecognized positively, and at the same time, the three dimensions of motion-state.

The result shows that only 45% of them conceive that the inertial movement can continue without the need for something to move it (I.D), and that itsstate is preserved within time (T.D) and even when changing the location (S.D).

III. Conclusion

The concept of motion-state, widely studied in its details by science historians and physicists, did not drive to the same interest during its didactic transposition even though it remains the key concept of the principle of inertia.

The perseverance of inertial motion, while keeping the same state of motion, is not sufficiently anchored in the conscience of the interviewed physics teachers of senior secondary school. Indeed, the results of our study show that many of these teachers find difficulty conceiving at the same time: The new form of intelligence that accompanied the principle of inertia consisting on the fact that the inertial movement can continue in the same state without the need for something to move it, That the state of inertial motion is preserved within time, and therefore this state is the same at all times, and finally, that this state also retains spatially at any point of the straight path traversed.

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