Elementary dynamics in Algerian secondary school: difficulties of assimilation and contribution of modeling activities in the construction of the notion of force

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ABSTRACT
This work attempts to analyze the conceptual difficulties encountered by Algerian secondary school pupils aged (14-17) when studying mechanical school situations that can be modeled in terms of force. Based essentially on a qualitative method, and more specifically on the analysis of data collected after the completion of a questionnaire and in individual interviews, this study has, on the one hand, highlighted Difficulties related to modeling activities, on the other hand elucidated their causes.

KEYWORDS
Force, difficulties, assimilation modeling activities, conceptions

RÉSUMÉ
Ce travail tente d'analyser les difficultés conceptuelles rencontrées par les lycéens algériens âgés (14-17) en étudiant des situations scolaires mécaniques modélisables en termes de force. Basée essentiellement sur une méthode qualitative, et plus spécifiquement sur l'analyse des données recueillies après l'achèvement d'un questionnaire et des entretiens individuels, cette étude a, d'une part, mis en évidence les difficultés liées aux activités de modélisation, d'autre part élucidé leurs causes.

MOTS-CLÉS
Force, difficultés, activités d'assimilation modélisatrices, conceptions

INTRODUCTION

Over the past thirty years, several research studies in science education especially in physics have shown that students who receive the first courses in mechanics, even those with deeper instruction, face difficulties in learning the key concepts of this discipline. Viennot (1989, 1996) detected a typology of systematic responses to elementary mechanical situations involving the concept of force. The conceptions underlying this typology are based mostly on coherent natural beliefs. The author summarizes the various characteristics of these responses:

(a) Adherence between the notion of force and speed "(more generally: momentum, movement, impulse ...)", "*The forces acting on the balls are different since the movements are*" "*The force is zero since the speed is zero*".
(b) Indecisive in the temporal location of the sizes: "At the top of the trajectory there is gravity and the force of the thrower's gesture (which act on the ball).
(c) Assignment of force to the object: "the force of the mass upward, otherwise how would it hold in the air at the top of the trajectory?".
(d) Idea of capitalization: the cause of the movement stored in the object in the form of an undifferentiated dynamic capital plays the role of a provision likely to be depleted.

Warren (1979) maintains that the third law is misunderstood because textbooks and teachers usually present it in a form something like 'action and reaction are equal and opposite'. He suggests that the terms "action" and "reaction" imply a time-sequenced cause and effect relationship where the forces of a third law pair arise simultaneously from the same interaction. Perhaps, this is why many pupils associate the third law with the condition of equilibrium.

Mohapatra and Bhattacharyya (1989) have shown that the various formulations of the law of inertia are misunderstood by the pupils. Certain expressions used in the statement of this law do not help the pupils to grasp its physical content; he also concluded that some erroneous extrapolations and generalization abuses lead to errors in the study of elementary mechanical situations.

In a study of a multicultural population, Enderstein and Spargo (1996) validated the predominant view that the resulting force exerted on a system always acts in the direction of movement in order to maintain it. As for Clement (1982, 1983), showed, moreover, that the pre-Galilean conception "movement implies force" resists teaching and is a source of persistent difficulties which hinder the appraisal of Newton's 2nd law (Finegold & Gorsky, 1991; Palmer, 1997), lies in the fact that they all fit within the framework of A research program that takes into account only the spontaneous conceptions of the students to explain their learning difficulties. To our knowledge, few studies have used modeling activities to identify the origin of these difficulties. In this article, we attempt to present a study whose objective is to describe the difficulties encountered by Algerian pupils in first year secondary school when studying usual school situations whose modeling requires the use of the force concept. That is why, we have relied on the concepts of conceptions and modeling activities to give meaning to the learning difficulties of one of the most fundamental concepts of mechanics, in this case, force. As several authors argue (McClosky, 1983; Viennot, 1989), certain difficulties in the learning of mechanics are not mere accidents; on the contrary, they rely on well-established natural beliefs. Viennot recalls that mechanics was one of the most important domains of physics for which we were led to try to know the "spontaneous" or "natural" reasoning of pupils and students. She stated that "Newtonian mechanics is typically the place of opposition between ideas and reasoning of common sense and the theory taught. It is not that it is difficult to state the fundamental law of dynamics or the law of reciprocal interactions (3rd law) for two systems. Simply for many physical situations, the answers that common sense dictates and those that allows for smooth acceptance are frankly opposed to Newtonian analysis".

In this research, we attempt to answer some questions, such as:

- What are the difficulties encountered by pupils (in the last year) of middle education in Algeria when studying mechanical school situations that can be modeled in terms of force?
- To what extent can modeling activities provide support, alongside with conceptions, to understand these difficulties?

- In other words, are these difficulties partly due to a non-initiation of the pupils to the activities of conceptualisation to mechanics?

WHY FOCUSES ON THE FORCE'S LEARNING DIFFICULTIES IN RELATION TO MODELING ACTIVITIES?

Force is a fundamental concept in mechanics, however, it is important to note that the literature on misconceptions focuses mainly on pupils and students and not on teachers or training to become teachers. Yip (1998) explains that this tendency rests on the unfounded assumption that being graduate of higher studies, teachers/trainees possess the knowledge needed for teaching the required content in the classroom. The author further, states that one source of pupils difficulties is the erroneous concepts propagated by teachers and textbooks. Indeed investigations revealed that teachers/trainees evidence conceptions difficulties as well (Galili & Hazan, 2000; Vellopoulou & Ravanis, 2012). Therefore, it is important to consider as well pupils as trainees and teachers when investigating misconceptions. This lack of understanding the concept of force, though sad, is not surprising. According to Hellingman (1992, p. 112) "We face the undeniable fact, hard it is to believe, that not only student but also professional physicists to quite a large extent do not have a full understanding of the concept of force". But according to Lemeignan and Weil-Barais (1993), difficulties in the acquisition of the Force concept are mainly due to the specificities of this concept. Unlike the quantity of motion or energy of the transferable and conserved quantities describing a system, force is a non-transferable and non-conserved quantity which describes a certain type of relationship between systems, a symmetrical relation (mutual interaction). Force is not an intrinsic property of an object. An object has no Force in itself. It is a conceptual tool used to model the interaction between objects or systems.

The difficulties encountered by pupils in the acquisition of the first notions of mechanics are often attributed to a lack of pupils' mathematical knowledge. On the other hand, we think that these difficulties are rather due to the fact that pupils are not initiated into the intellectual processes specific to elementary physics, in particular modeling activities.

Looking at the textbooks, we find that the Force is always introduced as a concept that describes a category of objects, whereas it is a concept, in fact, the categorization of the force (contact force, distant force, localized, distributed, etc.) is at the origin of certain conceptions of anthropomorphic origin. Lemeignan and Weil-Barais (1993) argue that when classifications are introduced at the beginning of the teaching of a fundamental physical quantity such as Force, pupils are implicitly reinforced that the conceptions of physics are of the same nature as those with which they are familiar in everyday language (table, car, book). Indeed, the assimilation of force to a categorical concept and all the more easy, especially since force is designated by a familiar term with a polysemy accentuated in everyday language.

However, for the pupils who learn the key concepts of physics, we think it is desirable to highlight the difference between common sense and the conventional meaning of the concept taught. The aim is to ensure that learners can create new structures of thought by themselves.

METHODOLOGY

Our study was undertaken with 49 pupils aged (14-17) who were continuing their studies in the first year of secondary school during the school year 2014/2015 (the year in which we carried out this investigation)

The purpose of this investigation is to highlight the difficulties encountered by pupils in simple mechanical situations that call for the vector representation of forces exerted on an object at rest or in motion.

The investigation took place in two phases. As a first step, subjects were asked to respond individually and in writing to a questionnaire containing six situations (see Annex); the question put for all situations consists in representing schematically the forces exerted on the object A (system to be studied). We have chosen situations where the system in question is at rest or in motion in different directions.

In a second step, subjects were interviewed individually to explain clearly some of their ambiguous responses. Each interview, carried out in the form of a session of about twenty minutes, was recorded and transcribed.

Since we have to deal with responses in the form of discourse and schematic representations, we have used the content analysis of these discursive and schematic productions. The first work of analysis consists of subdividing the output of the pupils into three categories from the perspective of the modeling activities to achieve this categorization. Indeed, the three categories of responses obtained belong to three types of modeling activities that we deemed necessary to conceptualise the notion of Force. It is:

(a) The intellectual activity which consists in cutting out by thought the physical universe into a system of study and external environment;

(b) The modeling activity consists in listing schematically the forces modeling the mechanical actions in terms of forces that apply to the system to be studied;

(c) The physico-mathematical activity which consists in representing schematically the forces modeling the mechanical actions that are exerted on the system in question.

These three types of modeling activities commonly practiced in mechanics are used as a grid of analysis of the difficulties encountered by the subjects of our sample.

PRESENTATION AND DISCUSSION OF RESULTS

The analysis of the data collected after the questionnaire administration and during the interviews, allowed us to identify the difficulties due to the non-initiation of the pupils to the activities of modeling. These are the following modeling activities:

- Identification of the system to be studied;
- Inventory of forces acting on the system;
- Representing these forces with the help of the entities.

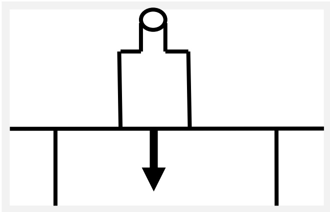
Indeed, when studying a system mechanically linked to other objects, the modeling of the interactions in terms of force between the system to be studied and the external medium requires the practice of the above-mentioned modeling activities in order indicated below. It follows that it is impossible to make an inventory of the forces exerted on a system which has not been well known beforehand. Similarly, we cannot represent the forces that model interactions that have not been identified before.

Difficulties related to modeling activities

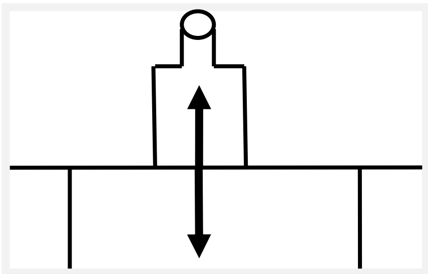
Difficulties related to the definition of the system studied

In case the pupils do not specify clearly the system to be studied (surrounding it by a closed line for example); the balance of forces is an index that will allow us to identify the difficulties pupils have with respect to this activity of modeling. In this way, we can distinguish the following difficulties:

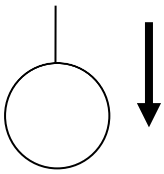
(a) The balance of forces includes forces exerted by the system itself on other objects (59%). For example, "*The bottle A exerts a force on the table*" (P3, S1) (the code "P3, S1" means an extract from the response of pupil 3 to situation1 - S1 represents the object A (a bottle) on a table).



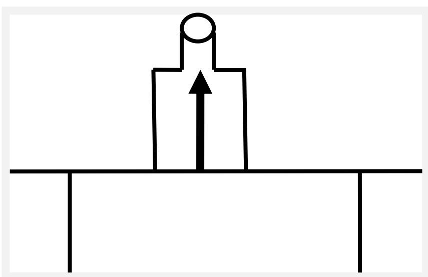
(b) The force balance includes forces that model reciprocal actions between the system to be studied and other objects directly or indirectly connected to the system in question (14%). For example "*The bottle A exerts a force on the table and the table exerts a force on the bottle A, That's why the bottle A is at rest*" (P32, S1).



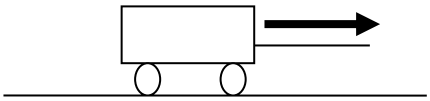
(c) The force balance includes forces exerted on systems other than the system in question (20%). For example "*The arrow represents the force exerted by the object B on the wire and the pulley P*" (P18, S4).



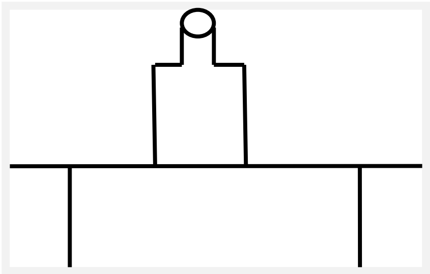
Difficulties related to the inventory of forces exerted on the system to be studied
If the pupils succeed to identify the system to be studied, which is not often the case, they run up against the difficulties related to the inventory of forces. In this connection we have identified the following difficulties:
(a) Inventory of forces is reduced to contact forces (55%) (P26, S1).



(b) The balance of forces exerted on the system in question is reduced to a single force acting on the object in the direction of the movement (65%) (According to P14, S5).



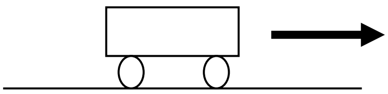
(c) The inventory of forces is zero, in other words the existence of the forces acting on a system at rest is denied (5%). For example, "*Object A is parallel to the table. The latter is horizontal; it exerts no force on A*" (P8, S1).



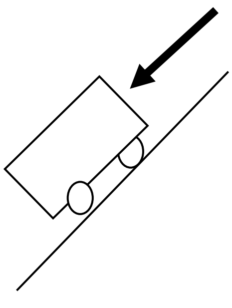
Difficulties related to the schematic representation of forces

Several difficulties are encountered by pupils in activities relating to the schematic representation of forces. We are content here to present those encountered by the majority of our sample.

(a) The balance of forces is represented by a segment oriented in the direction of the movement. For example "*The force exerted goes from A to pulley P*" (P20, S4).



(b) The direction of the force vector is oriented from the object that exerts the force to the one undergoing it (80%).For example, "*The arrow represents the force exerted by the wire on object A*" (P12, S2)



In short, the modeling activity of conceptualizing an intuitive notion such as force through an abstract mathematical notion i.e. the vector is far from being gained by most of our subjects. Indeed, pupils still represent Force by an arrow drawn no matter how and anywhere without any label. This shows that students face difficulties in making the vector-force model work, even in familiar school situations.

Let us recall once more that the difficulties outlined above are explained by the specific character of Force. It describes, as we have emphasized several times, not a system but the reciprocal interaction between systems. This fact is new for pupils who conceive force as a capital stored in an object that transfers it to another (idea of impetus, Koyré, 1980; McCloskey, 1983). Are not the expressions "having force" and "giving force" often referred to in everyday language? Thus, Force is conceived by daily reality as an inherent characteristic of objects. Can we not conclude from these that the difficulties associated with the modeling activities partly depends on the difficulties due to spontaneous conceptions?

Concepts underlying these difficulties

A careful analysis of the written productions of the subjects as well as their discourses, allowed us to locate a typology of response in disagreement with the Newtonian view point of mechanics. The difficulties underlying these responses are not mathematical, contrary to a commonly accepted idea, but they are, in our view, due to the students' conceptions of the Force. In the table below, we have linked each difficulty to an underlying design.

TABLE

Difficulties and underlying designs

	Related difficulties	**Underlying Conceptions**
Activity A: identify the system to be studied	-Balance includes forces acting by the system on other objects (60%). -Balance includes forces that translate reciprocal actions between the system and other objects (14 %). -Balance includes forces exerted on systems other than the system studied (20%).	Non-assimilation of the notion of interaction, a precursor concept necessary for the acquisition of force.
Activity B: balance of forces	-Balance is reduced to contact forces (55%). -Balance is reduced to a single force acting in the direction and direction of movement (65%). -Balance of forces is zero (in the case of immobility) (14%).	- A distant action requires a conductive intermediary. -Force implies movement -No movement implies no force.
Activity C: representation of forces	-Balance is reduced to a single force represented by an arrow oriented in the direction of movement (65%). -The direction of the force is always oriented from the object which exerts the force towards the one who undergoes it (80%).	Movement-The objects have force (students conceive force as a capital stored in an object that can be given to another (idea of impetus) Force implies.

Moreover, we believe that the use of the difficulties mentioned above helps pupils to perceive the profound difference between a causal approach in terms of properties and a modeling approach in terms of concepts and the relationship between these concepts. The first approach consists in relating the properties of objects and, on the other hand, the effects. The second approach is to represent the objectives in terms of a model and to retain that which is relevant to it (Lemeignan & Weil Barais, 1993). According to these two authors, causal inferences only intervene in the natural process on the empirical level, whereas in the modeling process, inferences require the use of a hypothetical representation and calculations on this representation.

CONCLUSION

In conclusion, we can argue that the sources of difficulties encountered by Algerian pupils at the first year of secondary schooling when learning the notions of mechanics can be explained by the failure to integrate the processes of modeling and conceptualization in the cognitive structures of pupils. These activities are virtually absent in didactics practice. Indeed, we find that in the current teaching of physics, in the secondary school (3 years), the experiments are carried out for the sole purpose of sticking to prefabricated models. Moreover, symbolic representations of concepts are not discussed. Students are led to accept ready-made models without being involved in the intellectual processes such as (problematisation, conceptualisation, modeling, formalisation, etc.) that lead to their elaboration. He is simply solicited to apply these models in order to answer written questions about situations themselves described.

Thus, concepts and models are presented in the form of statements that disconnect the intellectual processes that have produced them. These arguments allow us to infer that physics as taught in Algeria, like several countries around the world, amounts to stereotyped formulas. To overcome these difficulties in learning physics, we believe that the activities of conceptualisation and modeling must be at the heart of any teaching of physics from the secondary to the higher education (Hancer & Durkan, 2007; Voutsina & Ravanis, 2013; Halim, Yong & Meerah, 2014).

As for spontaneous conceptions, our results corroborate once again the hypothesis commonly accepted by didacticians: “formal education as it is practiced today (inductivism or intuitivism) has little impact on the destabilisation of initial conceptions”. Indeed, natural conceptions are tenacious because they resist teaching. It will be understood, therefore, that if the pupil is presented with notions contradictory to what he thinks or if he does not perceive the interest, he will not tend to take them into consideration. This explains, for example, that even after teaching about the Force, students continue to think of Force as an intrinsic characteristic of a system and that it acts in the direction of movement.

In teaching situations, the pupil is rarely asked to explain his initial ideas in order to become aware of them. He is also rarely asked to take into account clearly the difference between what he thinks and what he learns. This leads him to ignore new ideas that are transmitted to him because they do not integrate into his cognitive structures. Exactly the same as he invited to use a new symbolism to represent forces. He tends to believe that this is only a way of expressing himself. Thus, he changes neither an explanatory paradigm nor a conceptual register: he projects his spontaneous notional arsenal on physical situations without feeling the need to change the reading grid (Ravanis, 2010).

It should also be noted that most textbooks suggest an inductive approach where the approach should be partially hypothetico-deductive (Taibu, Rudge & Schuster, 2015). In fact, terrestrial attraction, perfectly smooth surfaces, wires without mass, are all fertile hypotheses posed by physicists to construct their models (Galili & Kaplan, 1996; Galili & Bar, 1997). However, although the inductive approach of physical concepts is much more accessible to students than the hypothesis-based approach, we agree with other authors that adopting a hypothetic-educational approach to teaching the Force is unavoidable.

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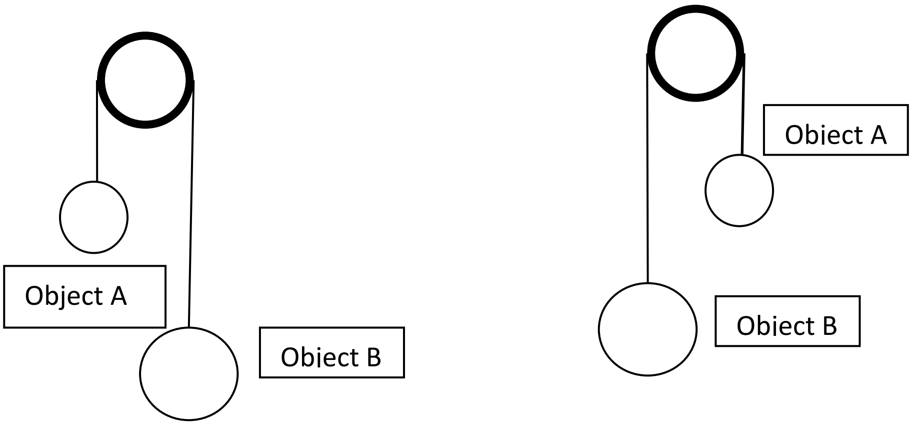
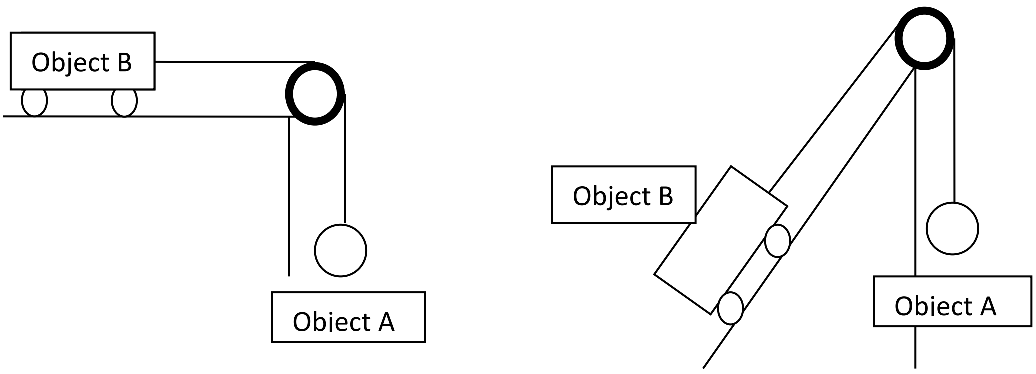
Annex

Situation 1 & 2



Situation 3 & 4



Situation 5 & 6