INVESTIGATION ON TEACHING AND LEARNING MECHANICS IN THE TERMINAL SCIENTIST CLASSES OF BURKINA FASO SECONDARY SCHOOLS

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Abstract

Teachers, learners and Physics inspectors are concerned by the poor performance of learners in mechanics in class context and in their year-end results. The year-end results show 35.9% in 2010 and 46.6% in 2011 as percentage of success in physics due to their poor performance in mechanics. Based on these observations, our research question can be expressed: Why after several years of teaching and learning mechanics, scientific senior learners of Burkina Faso secondary schools are uncomfortable in mechanics? For the investigation, twelve class situations have been observed with three teachers. On the other hand hundred and forty three students' productions have been analysed after their evaluation. Two research hypotheses have been set and guide our research: (1) Students of terminal scientists are not able to appropriate and integrate concepts and laws of kinematics and dynamics in problem solving and (2) The lack of mastery of content in kinematics and dynamics by students is due to their lack of mastery of mathematics tools. The present study showed that teachers did not take into account students' misconceptions and did not practice teacher-students and/or students-students interactions in class. They did not also practice interdisciplinary. Students' productions analysis showed that their poor performance also came from their incapability to contextualize their mathematics knowledge in physics and/or their difficulty to correctly use frames and vectors.

Keywords : Learning, Difficulties, Mechanics, Pedagogical practices

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1. Introduction

Several studies concern students' difficulties in mechanics (Viennot, 1975 ; Osborne, 1981 ; Clément, 1982 ; Viennot,1982 ; Menigaux, 1986 ; Viennot, 1989 ; Gunstone, 1990; Lounis, 1990 ; Aubert, 1994 ; Robardet, 1995 ; Viennot, 1996 ; Palmer, 1997 ; Vigoureux, 1997 ; Brasquet, 1999 ; Maarouf and Kouhla, 2001 ; Mildenhall and Williams, 2001; Palmer, 2001; Badly, 2002; Baldy and Aubert, 2005; Coulaud, 2005 ; Kima and Pak, 2002; Kobéna and Ouattara, 2008 ; Koffi, 2010; Oké, 2010). In Burkina Faso, for improving students learning conditions, many papers treated students » difficulties in electricity (Koné, 2007; Koné and Ouattara, 2009 ; Somé, 2007 ; Somé and Ouattara, 2009), in mechanics (Kobéna, 2006; Kobéna and Ouattara, 2008; Belemkoabga, 2012; Ouédraogo, 2012). During the year 2011, Ouédraogo (2012) analyzed the performances of two scientific senior classes with 55 and 58 students in mechanics and found that only 2% of each class succeeded in mechanics. Moreover, Belemkoabag (2012) during his work found that only 22.35% of students of first form secondary school succeeded in mechanics. These observations let us ask this research question: *Why after several years of leaning and teaching mechanic , scientific senior learners of Burkina Faso secondary schools are uncomfortable in mechanics?*

For the present study, we analyzed data carried out from class observations (12 teachers' lessons) and students' productions (hundred and forty three students' evaluation copies).

Several studies have revealed that common sense is responsible of learners' difficulties (e.g. Bachelard, 1938; Viennot, 1990; Trésarrieu, 2000 and Baldy, 2005). In fact, according to Gueorguiva (2002) didactic researchers remarked that students' representations persist beyond science education. The teacher can, at first, think that students have not properly learned, or he himself, has tackled the wrong way. Only the attentive teacher soon realizes that despite the change in teaching techniques used and time spent on the topic, despite the personal work of students, common sense is not buried very deep beneath the layer of physical meaning. Teacher strategy for overcoming common sense obstacles must follow the three steps: (1) to identify the expression of common sense (Viennot, 1996); (2) to be able to understand the reasoning underlying and (3) to bring students to correct their spontaneous thoughts. Therefore, Viennot (1996) argued that beyond the acquisition of the concepts themselves the essential result might be the transformation of students' attitudes.

Kim and park (2002) in their work did not find students' difficulties with physics formula and mathematics but in Burkina Faso many studies showed that students are uncomfortable with mathematics tools in physics (Kobéna and Ouattara, 2008; Somé and Ouattara, 2009; Belemkoabga, 2012; Ouédraogo, 2012). Ouattara (2005) showed that in secondary schools, French scientific juniors are uncomfortable with differential equations appeared in their physics program. The same thing have been pointed out by Somé and Ouattara (2009) in electricity with Burkina Faso scientific juniors. In mechanics in Burkina Faso, Kobéna and Ouattara (2008) noted the difficulty of students with vectors, geometrical constructions and graphic methods. Moreover, Belemkoaga (2012) pointed out that scientific first form students had difficulty with gravity potential energy concept. Our study focuses students' difficulty in mechanics and especially in kinematics and dynamics. The second section of the present work concerns teaching and learning context. The third and fourth sections are devoted to materials and methods and results and discussion, respectively. In section five, we test our hypotheses and end the work by conclusion as its sixth section.

2. Teaching and learning context

2.1 Objectives

Physics teaching has the following objectives: (1) allow learners' acquirement of scientific methods; (2) develop students' creativity, curiosity, work autonomy and critical spirit; (3) allow the acquirement of basic scientific concepts.

The well known of Newton's laws in a case study will permit them to (1) model and apply dynamics laws in analytic method of solving problem; (2) quantitative experiment and compare theoretical results with experience with a view to improve the model processes.

2.2Mechanics curriculum in scientific senior classes

The mechanics program is constituted of seven chapters based on the teaching of kinematics and dynamics. We have: Element of kinematics, Newton's laws of motion, kinetic energy, motion in uniform gravitational field, electric particles motion in uniform magnetic field, mechanics oscillations.

We will focus our attention on the first four chapters as the others constitute their application. On the other hand they need other parts of the curriculum that deal with electricity and magnetism which are out of the topic of the present investigation.

2.3 Teaching methods and techniques

The spirit of physics program is strongly oriented toward experience. Therefore, two ways are offered to teacher during his job processes: lesson experience in which teacher himself experiments and learners act like observers. The second process is the experimental method in which students experiment. In that case, they constitute a group of 10-12 students and use didactic panels for the manipulation. These two ways must give to students the capabilities that expected by the program developers through program objectives.

3. Materials and Methods

3.1 Sample

For the present study, 236 students with 16-23 years old are involved. They arrive in the scientific senior classes after 4 years of initiation in classical mechanics. The concerned schools are two public schools (Lycée Marien N'Gouabi (LMN) and Lycée Municipal Rimvougré (LMR)) and two private schools (Lycée Privé Yiguia (LPY) and Lycée Privé Dimdolobsom (LPD)). The number of students per schools is: LMN1 (59 students), LMN2 (55 students), LPY (57 students), LMR (20 students) et LPD (45 students). Where LMN1 and LMN2 design LMN two classes. Based on the number of class, five teachers are involved with two teachers from LMN and for the others, one teacher per establishment; Four fifth of teachers have pedagogic diploma name Vocational Aptitude Certificate of Secondary School. This study has been done during scholar year 2011-2012.

3.2 *Instruments of assessment*

Two methods have been used to collect our data: (1) ***Class observations*** by means of observation grid conform to Burkina Faso official class observation grid. We observed twelve class sessions with three teachers. The observed class situations are constituted by eight lessons and four exercises sessions. (2) **Evaluation test** that subject is given in annexe. Only 143 students have been evaluated.

3.3 Hypotheses

We set two hypotheses to guide our data analysis:

1. Students of terminal scientists are not able to appropriate and integrate concepts and laws of kinematics and dynamics in problem solving.

2. The lack of mastery of contents in kinematics and dynamics by students is due to their lack of mastery of mathematics tools.

Table 1 gives the indicators of the hypotheses

Table 1: Hypotheses indicators

Codes	Evaluated contents	Hypotheses
C_1	Galilean reference frames, relativity of the motion	H_1
C_2	Newton's laws	
C_3	Kinetic energy theorem	
C_4	Mathematics tools	H_2

We adopt 75% of confident level in our study. This means that hypothesis 1 is verified when 75% of students marks are superior or equal to 10/20. The second hypothesis is verified if less than 75% of students succeed to less than 75% of test items that address mathematics tools.

4. Results and discussion

4.1 Presentation and analysis of class observation data

In class, the contents taught are consistent with the program content but teachers did not control students' prerequisites, motivate learners and evaluate the pedagogic objectives of the lessons. On the other hand they did not give homework after lessons. The basic sources of students difficulties in class are due to teachers' practices that consist to "knowledge transmission" because there is no direct interaction between teacher and students and also between students and students. But efforts are done by teacher to explain some parts of the lesson that seem to be difficult, to answer to students questions or to question students. Moreover, mathematics tools are not properly contextualised, any effort is made to highlight students' misconceptions and no interdisciplinary procedures. Excellent solutions have been proposed by Ouattara (2005) for permitting good contextualisation in physics for permitting to overcome students' difficulties coming from bad contextualisation or absence of contextualisation. Even thought physics and mathematics programs are so rigid it is possible for teachers to harmonize their schedule for applying a kind of interdisciplinary. It can be noted that there is any experimentation in class while it is well known that experimentation increases the efficiency of physical sciences teaching (Richoux, 2000). This situation comes from the lack of laboratories in most of secondary schools.

4.2 Presentation and analysis of students' productions

Table 2 gives students' marks after evaluation. It can be seen that only 15% succeed. This shows learners are uncomfortable with mechanics after teaching.

Table 2: Synthesis of students' marks

Marks	**[0;2[**	**[2;4[**	**[4;6[**	**[6;8[**	**[8;10[**	**[10;12[**	**[12;14[**	**[14;16[**	**[16;18[**	**[18;20[**	**Total**
Number of students	6	25	40	32	19	13	5	2	1	0	143
Total	**122** (85%)					**21** (15 %)					

For well known where students are more uncomfortable, we will analyse their performance per item with respect to table 1. Students' evaluation copies are examined and we attribute the term "succeed" for good response and "fail" for bad response.

4.2.1 Galilean reference frame and motion study

Students' marks for this code can be observed in table 3. Table 3 shows seven items in relation to Galilean reference frame and motion study. General analysis of this table shows that students are uncomfortable with reference frame and are not able to determine an object trajectory in case of free-fall. They have more difficulty with non Galilean reference frame in case of circular motion (1% of succeed: item I_4) and trajectory determination with initial horizontal velocity (2% of succeed: item I_7) than with the recognition of Galilean refrence frame (28% of succeed: item I_2 and 26¨% of succeed: item I_1). It can be retained that more students was able to determine an object trajectory in general case (22% of succeed: item I_5) curiously they did not in specific cases (15% of succeed: item I_6 and 2% of succeed: item I_7).

Table 3: Students' performances in relation to Galilean reference frame and motion study

Items	Evaluated Knowledge	Succeed		Fail	
		Number	%	Number	%
I_1	To recognize Galilean reference frame in case of static object	26	**18%**	117	**82%**
I_2	To recognize Galilean reference frame in case of uniform rectilinear motion	28	**20%**	115	**80%**
I_3	To recognize non Galilean reference frame in case of non uniform rectilinear motion	12	**8%**	131	**92%**
I_4	To recognize non Galilean reference frame in case of uniform circular motion	2	**1%**	141	**99%**
I_5	To determine the trajectory of an object in case of free-fall by using the initial condition of its motion	22	**15%**	121	**85%**
I_6	To determine the trajectory of an object in case of free-fall without initial velocity	15	**11%**	128	**89%**
I_7	To determine the trajectory of an object in case of free-fall with initial horizontal velocity.	3	**2%**	140	**98%**

4.2.2 Newton's laws and their applications

Table 4 presents students' performances in relation with their capability to enounce Newton's laws and to use them in concrete cases. Table 4 analysis shows that students do not know the laws definition and consequently are uncomfortable with their applications. Even if students show poor performance with laws, the best performance (25%) is observed with the second law and the worst with third law (3%). Their performances with first and third laws are fairly similar. The best performance with the laws definition is observed in item I_9 (second law definition in red in table 4) and with its application in the case of an object motion on an incline (item I_{13} in blue in table 4). It can be retained that students can know law definition but be uncomfortable in problem solving (e.g. they are more uncomfortable with item I_{14} than with item I_{13} that address the same second law application in different cases study).

Table 4: Students' performances in relation with Newton's laws and their applications.

Items	Knowledge evaluation	Succeed		Fail	
		Number	%	Number	%
I_8	To enounce Newton first law	5	**4**	138	**96**
I_9	To enounce Newton second law	35	**25**	108	**75**
I_{10}	To enounce Newton third law	4	**3**	139	**97**
I_{11}	To apply the second law for finding system acceleration	33	**23**	110	**77**
I_{12}	To apply the second law for getting system external force	11	**8**	132	**92**
I_{13}	**To apply second law in the case of an object motion on an incline**	**49**	**34**	**94**	**66**
I_{14}	To apply the second law for getting system force	25	**18**	118	**82**
I_{15}	To identify and highlight interaction forces	10	**7**	133	**93**
I_{16}	To apply kinetic energy theorem in the case of an moving object on an incline	39	**27**	104	**73**

Copies examination exhibited that even though students were not able to properly enounce laws, they knew mathematical expressions of laws. The analysis of their productions addressed item I_{13} where they have got their best performance, we noted that they did not used reference frame given to them, some vector expressions are equal to scalar expressions and they left vector expression and went to scalar expression without projection. These procedures highlight the bad contextualisation of their mathematics procedures in physics. The same procedures have been observed in class context and pointed by Kobéna and Ouattara (2008) during their works.

Students' performances in item I_{15} is conformed to that with item I_{10}. This seems to be normal because item I_{15} constitutes the application of the third law (item I_{10}). Students' difficulty with this law comes from classroom where because of teachers' procedures this seems to be valid in the static cases. Viennot (1996) resumed all interaction problems as:" *By thinking that force is coming from the object and sometimes lag times distort the understanding of interactions between two objects, especially in a situation where both are moving. The law of physics states that their mutual actions are equal in intensity: the driver who accelerates the car by pushing down firmly to the garage, in turn undergoes a force exactly opposite. The wrestler who takes the advantage over his opponent and collapses on him is no exception to this rule: he never exercised his rival on a force greater than that suffered its share*". Moreover, she affirmed that "*It is often believed that an object performs its" weight" on its support. It is true that in equilibrium (although the wording is debatable)*". Viennot (1996) affirmation let us say that teacher must change their teaching procedure for facilitating learning conditions.

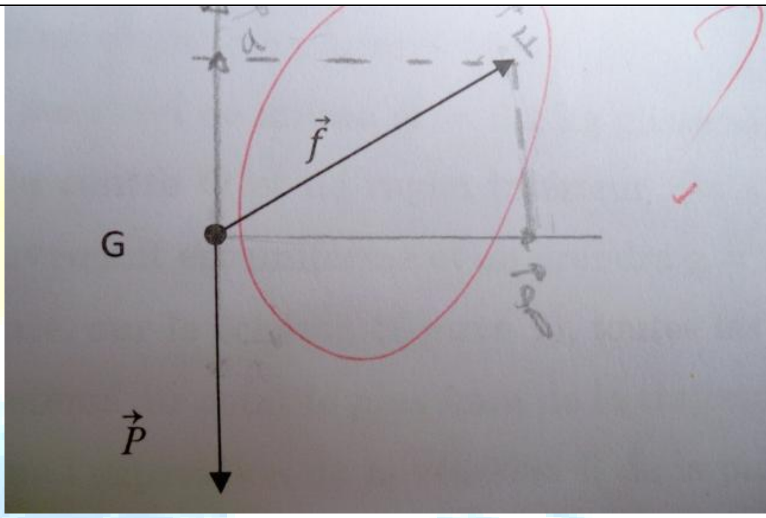
The examination of students' production in the case of item I_{16} pointed out that their difficulty is due to the determination of the work of weight. They did not know that this quantity can be negative. This situation comes from the teaching method of work of weight in third form. In this form, the absolute value of this work is seen and they used "motor work" and "resistant work" when the work of the weight is positive and negative, respectively.

4.2.3 Mathematics tools

The mathematics tools observed in the evaluation are the utilization of reference frame and vector construction. Reference frame is used in the case of the application of the second law and permits the obtaining of algebraic expressions after the vector projections. In the case of item I_{11} (see table 4) students must project the equation obtained by applying the fundamental principle of dynamics in the given reference frame. The analysis of their production showed that they did not use a given reference frame or did not know how to properly use it. In that last case they confused vector and its component after projection in x axis.

Vector construction is used in item I_{13}. It is important to note that this kind of construction has be seen in second form and constitute a part of mechanics program of this form. Kobéna and Ouattara (2008) have noted that students are uncomfortable with this part of curriculum. The presence of this difficulty means that they passed they class without overcame this difficulty. In figure 1 we give students' constructions. Panel a corresponds to "fail" construction and panel b to "succeed" construction. It appears in panel a that student does not know how to determine the resultant of the two forces. He ignores the weight vector given to him and tries to find the component of F force. In panel b it can be seen than student knows the all processes needed for the construction.

a



b

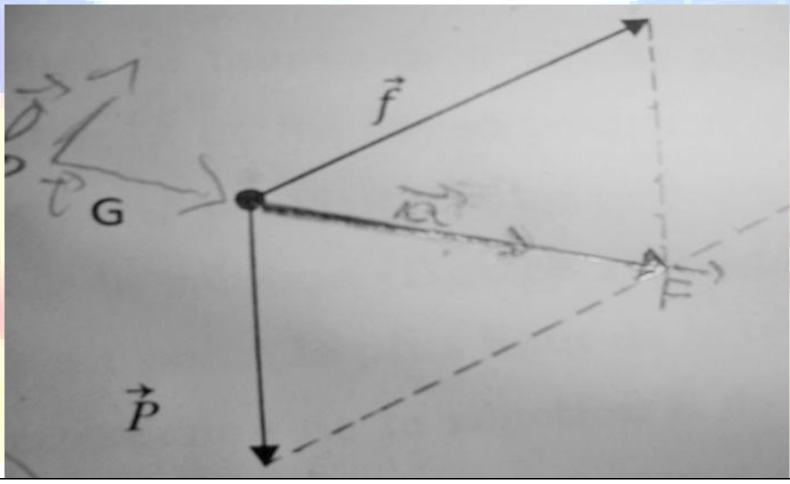


Figure 1: Determination of the resultant of two forces

5. Testing hypotheses

Table 2 gives students' performances percentages. Table 5 shows these percentages for all the items taken together. According to table 2 only 21% of students' marks are more or equal than 10/20. Moreover, hypothesis 1 is valid if less than 75% of students get the mean (10/20). Therefore we can conclude that our hypothesis 1 is valid.

The synthesis of our results with respect to mathematics tools shows that only 34% succeeded. However from table 5 it emerges that only 3% succeeded. Our second hypothesis test states that this hypothesis is valid when less than 75% of students succeed to less than 75% of the items related to mathematics tools. So it is evident that this hypothesis also is valid.

Tableau 5: Succeed items per hypothesis

Hypotheses	Total number of items	Succeed items by less than 75% of students (in percentage: %)
H_1	16 : $I_1 - I_{16}$	**3**
H_2	3: I_5 - I_6 6 : I_7 - I_{16}	**3**

6. Conclusion

The present study showed that students are not able to correctly define Newton's laws even thought they knew laws mathematical expressions. Students are uncomfortable with reference frame and vector. Class observation data showed that teachers' methodologies are responsible to students' poor performances in kinematics and dynamics. Teachers did not practice interdisciplinary and did not take into account students' misconceptions or common senses in their pedagogic methods. We suggest the collaborative work between physics and mathematics teachers for applying interdisciplinary and strongly recommend to teachers to try to find the expressions of students' conceptions and to act for overcoming them in order to permit students to properly build their knowledge. Government also must take its responsibility by providing secondary schools with functional laboratories.

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ANNEXE: SUBJECT OF THE EVALUATION TEST

Class : **Duration :** **04 hours**

First name :…………………………………………… **Last name** : …………………

Exercise 1 : *Galilean reference frame – Relativity of motion*

1°) The observation of the following objects with respect to terrestrial reference frame that supposed to be Galilean. Are the following objects Galilean? Justify your responses

a) Moving table in classroom.

b) Moving car in the case of uniform rectilinear motion

c) Moving car in the case of non uniform rectilinear motion

d) Moving motor in the case of uniform circular motion.

2°) From the top of a long mast attached to a moving truck (the motion of the truck is a uniform rectilinear motion), we drop a stone. The effect of air resistance is neglected. All answers must be justified.

a) The stone does fall behind, or before the mast?

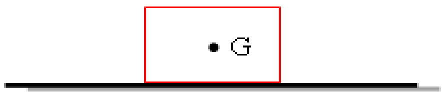
b) - What is the nature of its trajectory to an observer who is sitting in the truck?

- What is the nature of its trajectory to an observer who is stopped at the roadside?

Exercise 2: *Concept and motion laws*

1) Sets out each of the three Newton's laws

2) A body is on a flat horizontal table. The body and the table are stationary relative to Earth. Taking stock of the interaction forces between the body and the table. Represents them on the diagram below.



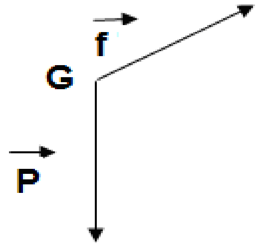
3) We consider a car (A) with mass m_A = 1200 kg that pulls a container (C) with mass m_C = 800 kg. All started on a horizontal road under the action of a driving constant force that is parallel to the displacement with an intensity F = 1000 N. Frictional forces are neglected. For simplicity, the car and the container will be considered as material points.

a) Represents, on a simplified diagram, the external forces exerted on the solids A and C.

b) Find the value of the acceleration of the system. What then is the traction force T_C that the car exerts on the container?

4) An object point with mass 2.5 kg is subject to two forces $\vec{f}$ and $\vec{P}$. Represents the resultant of the two forces $\vec{F}$ applied on the object point and determine the acceleration $\vec{a}$ of the object.

Scale: for forces: 1 cm corresponds to 10 cm and for acceleration 1 N corresponds to 6 m/s^2.



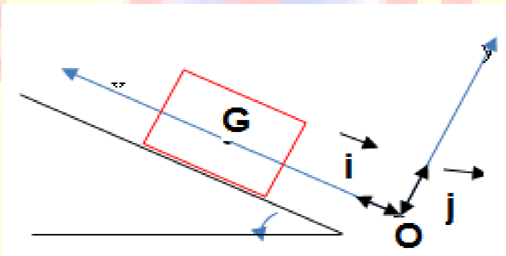
<u>Exercise 3</u> : *Motion on incline*

1) A body with a mass m and the center of inertia G, is launched towards the upper part of an inclined plane along the axis (O, X), with an initial velocity of v_0. At t = 0 s, the center of inertia is in O and the velocity is equal to v_0. Friction is neglected. It gives β = 30 ° and g = 9.8 m/s^2.

a) Represents the external forces acting on the body in the diagram.

b) Gives the coordinated expression of the a_x of the acceleration as a function of β and g.

c) We wish to reach a point distant d = 80.0 cm. Apply the theorem of kinetic energy for finding the minimum value to be given to the speed of v_0?



2) A car (with driver) has a mass m = 1000 kg. It mounted on an inclined plane by an angle α = 10 ° with respect to the horizontal, under the action of a driving force parallel to the displacement. For simplicity, we assumed that the car is timely and that the sum of the frictional forces is constant and parallel to the movement with the intensity f = 150 N. It gives g = 9.8 m/s^2.

a) Represents the external forces exerted on the car.

b) What is the value of the driving force F developed by the car if the car has a constant acceleration a with magnitude 5 m/s^2.