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(Research Article)

Teaching newton's second law in the final year of secondary school: Physics teachers' knowledge about subject content

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Abstract

Each teaching discipline has its own specific characteristics. Physics is no exception to this principle. To this end, the teacher of this discipline must have certain specific knowledge, including that of the disciplinary content, in order to practice the profession easily and effectively. An exploration, in the light of Shulman's model, of some of this knowledge in relation to Newton's second law in the final year of physics teaching reveals that these teachers have no mastery of the epistemology of their discipline, or of its scholarly and institutional functioning. As a result, it is unlikely that their teaching will enable the subject to achieve its objectives through the teaching and learning of its laws. A reorganization of the content of physics teacher training and retraining program could be beneficial for effective learning of the subject.

Keywords: Physics; Newton's Second Law; Subject Content Knowledge

1. Introduction

In this article we explore physics teachers' disciplinary knowledge of Newton's second law of motion in order to identify what might hinder the learning of this law. We begin by presenting the epistemological and didactic context of the study, followed by the conceptual and theoretical framework of the research and the methodological approach used. Finally, we present the results, which we discuss.

2. Research problem

2.1. From facts to the laws, principles and theorems of physics

All scientific progress is part of science's advance towards the discovery of the truth about the world and it is with this same aim in mind that physics, as a discipline, is devoted to the study of the facts of nature. The teaching/learning of physics therefore aims to build functional knowledge of the facts of the real world, through the laws, principles, theorems, axioms, etc. of physics. This is why it is said that the essential function of physics is to develop theories and models that enable it to explain and interpret facts (phenomena and events) and even to prevent certain events (Tiberghien, Vince and Gaidioz 2009). In the present study, which focuses on one of the laws of physics, Newton's second law of motion, we asked ourselves what relationship the laws of physics have with these facts. The answer to this question lies in clarifying the evolution from the facts of nature to the laws, principles and theorems of physics. These facts are either phenomena or events, depending on their intrinsic characteristics.

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Phenomena and events are derived from scientific facts, obtained by brief analysis and translation of the raw facts into language appropriate to physics. The heating up of an electrical appliance connected to a mains supply, the breakdown of a capacitor, the falling of a piece of fruit, a plane breaking down, etc. are examples of noisy facts. The transformation of electrical energy into heat by an electrical appliance through which an electric current flow, the destruction of the insulation of a capacitor under the effect of heat or an electric field that is too intense, and the fall of bodies under the effect of the Earth's gravitational pull are examples of scientific facts.

Sagaut (2008) provides a substantial clarification of the difference between phenomena and events in science in the following terms:

A phenomenon is a fact associated with a change, and which is repeatable: the falling apple is a phenomenon. Not every fact is a phenomenon, either because it does not involve change (e.g. the near-rotundity of the earth is a fact that is not associated with change or evolution), or because it is not repeatable (in which case it is called an event). An example of an event is the disintegration of an atomic nucleus, which occurs only once (Sagaut, 2008, p.33).

Thus, the fall of a fruit from a tree, the heating of an electrical appliance connected to a mains supply and the movement of the planets around the sun are phenomena, whereas the quasi-rotundity of the Earth, the breakdown of a capacitor, the disintegration of an atomic nucleus, etc. are events and are not phenomena either because they do not involve change or because they are not repeatable. Une telle clarification semble importante pour l'enseignant de la physique, qui est appelé, au cours de l'élaboration des séquences de classe, à tenir compte d'un certain nombre de particularités des faits pour une transposition didactique (Chevallard, 1985) adéquate, précisément lors du passage du savoir à enseigner au savoir enseigné. Since the facts of nature are generally complex, physicists always use the simplest possible models of analysis, interpretation and prediction to study them, as these are the most plausible representations of the real world. To achieve this, he makes hypotheses about the relatively stable characteristics of these facts, and when these are corroborated by numerous observations or applications, they are considered highly probable, generalised and given the name of laws of physics. In this way, the laws of physics are derived from facts, and are therefore observational. In this sense, we can agree with Sagaut when he states that "it is therefore inaccurate to say that facts are governed by laws: we must say that facts include laws" (Sagaut, 2008, p. 33). The term "laws of physics" is used here to distinguish them from legal laws, which are normative and govern the behavior of individuals in a given society.

A law of physics is therefore a scientific proposition that establishes a logical relationship between the different physical variables relevant to a fact and generalizes its essentially stable characteristics.

Most experiments relating to the experimental demonstration of Newton's laws of motion, and more specifically of the second, apart from the case of free-fall movements, generally have a high level of idealization and generalization. This is because, despite all the modelling done during these experiments, certain parameters are still difficult to pin down. This is the case, for example, with friction, air resistance and so on. We often have to extrapolate. But the results obtained are generalized. This is what Granger (1999) sometimes calls thought experiments. From this point of view, and given that in the empirical sciences, when a scientific law is so generalized and abstract, it is elevated to the rank of scientific principle (Granger, 1999), Newton's second law of motion has the full status of a principle of physics. A scientific principle is therefore defined as the statement of a scientific law with a high degree of generalization, deduced from observations of a set of facts, i.e. a proposition to be used as a basis for reasoning when explaining or interpreting these facts.

Even if, in the case of Newton's second law, it is not easy to demonstrate this proposition experimentally in all cases, it can still be demonstrated by logical reasoning based on given facts or justifiable hypotheses. In science, when a scientific principle has been demonstrated, it is called a theorem. This is what justifies the names Newton's second law of motion or the theorem of the centre of inertia of a solid (where the mass is constant), which we will use throughout this work.

2.2. Epistemological and didactic context

From the facts to the discovery of the scientific laws that govern them, the path is almost never linear. The results are also generally not the prerogative of a single individual but, for the most part, syntheses resulting from the work of several researchers (or teams of researchers) over a period of years, or even centuries. The form and/or formulation of the laws of motion of classical or Newtonian mechanics were no exception to this rule.

Indeed, the physics of motion began in the Aristotelian era and lasted until the second half of the 17th century, before the foundations of this mechanics were clearly laid down by Newton in his work entitled "Mathematical Principles of Natural Philosophy", published in 1687 but written a little earlier. Even though most of the scientists who had worked before Newton on questions of the movements of bodies and who had obtained certain results, despite the still perfectible nature of these results, were no longer alive to claim anything from Newton's work, this was not the case for Robert Hooke, who vigorously claimed authorship of the law of universal gravitation (Sagaut, 2008). He also criticised Newton for the fact that, throughout his work, he did not deign to cite at least his predecessors who had worked on the same questions and whose results he used as an essential basis. Newton, seeing these criticisms as too much, replied to Hooke with the famous phrase: "if I have seen further, it is by standing on the shoulders of giants" (Newton reported by Cariou, 2011). For him, this response of "partial" recognition could soothe people's hearts. In reality, this was only for a short time, since the same Hooke soon came back to the charge with the quarrel over hypotheses (Cariou, 2011). He demanded that Newton inform the scientific community of the hypotheses that had led to the discovery of his famous laws of motion and universal gravitation. Because of his highly-developed spirit of anticipation, he was still able to avoid the trap set for him by saying: "I don't make assumptions". What's more, he and his disciples described hypotheses as "the poison of reason and the plague of philosophy" (Newton reported by Cariou, 2011). Newton thus succeeded in imposing his empirico-inductive method as the legal scientific method for centuries. The triumph of his methodological precepts over time is due above all to the high degree of generalization of the laws he discovered using this method, which are corroborated by numerous satisfactory results.

But in the 19th century, voices began to be raised against this method of study in the experimental sciences, which was devoid of any hypotheses. This epistemological turnaround was formalized around the middle of the century by scientists such as Comte and his followers, who believed that in experimental science, hypotheses were the keystone of any study. Experiments must therefore be carried out with the aim of confirming or disproving a hypothesis formulated after observing certain phenomena or events. This aspect of the study process would later be reinforced by Canguilhem in the following terms: "reason is needed to conduct an experiment and experience is needed to form a reason" (Canguilhem reported by Cariou, 2011). From then on, the episode of hypotheses seemed to be definitively closed.

In order to iron out the differences of opinion on the methods of study in experimental science, Claude Bernard proposed the institutionalization of the following scheme: Observation - Hypothesis - Experiment - Results - Interpretation - Conclusion: Observation - Hypothesis - Experimentation - Results - Interpretation - Conclusion, known by the acronym OHERIC and recognized by contemporary epistemology as the scientific approach (Laugier and Dumon, 1998). It should be pointed out that in the teaching of certain scientific laws, where the teacher generally leads the learners to a verification, this scheme is very well adapted, only that it is sometimes far removed from the method that led to the discovery of the said laws. This is precisely the case, for example, with Newton's laws of motion, which Newton himself insisted he had discovered using his empirico-inductive method, i.e. without any prior hypotheses.

Since this is one of the laws whose teaching is the subject of study in this research project, let's see what these laws say in their original versions. The French translation, by Madame Marquise de Chastellet, presents them as follows:

First law: Everybody perseveres in its state of rest or uniform rectilinear motion unless imparted forces force it to change its state. Second law: The change in motion is proportional to the driving force imparted and occurs along the straight line by which this force is imparted.

Third law: Action is always equal and opposite to reaction: in other words, the mutual actions of two bodies are always equal and directed in opposite directions. (Sagaut, 2008).

We note that these laws of motion, in their original versions, are stated practically in a natural language register (Duval, 1993). However, the statements of these laws were very soon affected by the algorithmisation of the science of motion, especially with the development of differential and integral calculus by Gottfried Wihlelm Leibniz. This shift away from the qualitative towards the quantitative, or towards measurable physical quantities, can be explained by the rational and mathematical vision that certain scientists, such as Galileo, had of nature very early on, through the excellent formula according to which "the book of nature is written in mathematical language and its alphabet is geometrical" (Galileo reported by N'Guessan, 2019). With these words, Galileo emphasised the close link between mathematics and physics. And this is precisely what distinguishes physics from the other natural sciences (Paty, 1998). Newton's laws of motion were no exception to this mathematization of physics. It should also be noted that, when they are introduced into knowledge texts for teaching in secondary schools and universities, these statements (discussed above) generally undergo a number of arrangements or simplifications, taking into account the level of study. The reasons for this state of affairs or these processes are to be found in didactic transposition (Chevallard, 1985) and are not the subject of study in this research work. For example, in the textbook ''Physique Term S'' by Tomasino et al, 1999), these laws are set out as follows:

First law: In a Galilean reference frame, the centre of inertia G of a solid subject to a set of forces whose ($\sum \vec{F}_{ext} = \vec{0}$) is either at rest or animated by a uniform rectilinear motion ($\vec{v}_G = \vec{C}^{te}$).

Second law: In a galilean reference frame, the $\sum \vec{F}$ of forces applied to a point object is equal to the product of the mass m of the object by its acceleration vector $\vec{a}$.

Third law: When a solid S_1 exerts a force of $\vec{\ }_{(1/2)}$, the solid S_2 exerts on the solid S_1 the directly opposite force $\vec{F}_{(1/2)}$: $\vec{F}_{(1/2)} = -\vec{F}_{(2/1)}$ (Tomasino et al, 1999, p. p.p. 60, 63, 64).

There is a big difference in form between the statements in the original version and those in this textbook, and this can be seen in most of our school and university textbooks. In the ''Physique TermS'' textbook from the Durandeau collection, these same laws are set out as follows:

First law: In a Galilean reference frame, if the vector sum of the forces exerted on a solid is zero ($\sum \vec{F} = \vec{0}$), the velocity vector $\vec{v}_G$ of its centre of inertia does not vary.

Conversely, if the velocity vector $\vec{v}_G$of the centre of inertia of a solid does not vary, the sum of the forces exerted on this solid is zero.

Second law: In a Galilean reference frame, the vector sum $\sum \vec{F}_{ext}$ of the external forces applied to a solid is equal to the product of the mass of the solid by the acceleration vector of its centre of inertia: $\sum \vec{F}_{ext} = m \cdot \vec{a}_G$.

Third law: When a body A exerts on a body B a force $\vec{F}_{(A \to B)}$, then the body B exerts on A the force $\vec{F}_{(B \to A)}$.

Whether the bodies are at rest or in motion, these forces are opposed have the same support: $\vec{F}_{(A \to B)} = -\vec{F}_{(B \to A)}$. (Durandeau et al, 2006, p.p. 206, 211)

As mentioned above, these statements vary from one manual to another. However, the substance is always acceptable. In these and other textbooks, Newton's second law is reduced to the theorem of the centre of inertia of a solid, or the latter is simply replaced by a material point (so as not to consider the variation in mass) without any other mention. Other textbooks refrain from explicitly presenting statements of these laws.

The second law, which, in a Newtonian vision, should make it possible to explain, interpret or predict phenomena relating to the movements of bodies, is already truncated because these statements do not take into account the variability of the mass of certain bodies during their displacement.

Since the explanation is always made in relation to a given reference, this law, also known as the fundamental principle of dynamics, actually makes it possible to explain the difference between the effect induced by a force or resultant of forces on a body (the movement it causes or tends to cause) in relation to a natural reference movement, which is nothing other than the uniform rectilinear movement stipulated by the first law (Maron and Colin, 2016). It is in this sense that Newton's second law cannot function without the existence of the first, since it is precisely the first that defines the reference point against which the explanation or prediction will be made. This law, which is the subject of this study, is the law that Euler would later write in the form $\vec{F} = m\vec{a}$, the keystone of classical mechanics, and probably the first equation in the history of physics" (De Rop, 1994). It should be noted that it is in the case of a material point that the fundamental relation of dynamics boils down to Euler's equation. In our current language, maj $\vec{F}$is the resultant of the applied forces. This is a logical-mathematical relation (Oké, Kanffon and Kélanil, 2019), therefore grouping only theoretical entities. The question this may raise is how can purely theoretical or mathematical elements be used to explain real-world or empirical phenomena or events?

2.3. Theoretical and conceptual framework of the research

For this research, which forms part of a doctoral thesis, we chose to use Shulman's model (1986, 1987) as our theoretical framework. This model allows us to distinguish and categorize different types of teacher knowledge. These categories form the basis of teacher knowledge, the structure of which, after considerable debate, has finally been approved by researchers in didactics. Among these categories are subject-matter knowledge, which is the focus of this article. This refers to the knowledge that teachers are responsible for teaching students, but this subject-matter knowledge is not limited to what they must teach. Subject-matter knowledge can be of two kinds. It can relate to the organization of concepts, facts, principles, and theories, the rules governing the evidence used to generalize and justify the knowledge produced by the discipline (Schwab, cited in Abell, 2007).

In this article, we have chosen to explore the disciplinary content knowledge of physics teachers regarding the teaching of Newton's second law in the final year of secondary school.

3. Literature review

Physics, despite its specificities, makes much greater use of mathematics when implementing most of its laws. To this end, Dachraoui et al (2023) conducted a study of the content of training programs for future physics and chemistry teachers. The aim of this study was to see whether these programs took account of interdisciplinarity between mathematics and the physical sciences. They found that not only interdisciplinarity but also epistemology and the history of science were almost completely absent from the curricula. In this study, they succeeded in showing the importance of integrating these fields of training into the curricula in order to "...better prepare teachers to teach concepts in a relevant and practical way, while promoting pedagogical innovation and contributing to the development of tomorrow's scientific and technological talent" (Dachraoui et al, 2023).).

The concept of force is a pivotal concept in Newtonian dynamics. However, our current physics syllabuses in secondary schools introduce it as an entity with an autonomous meaning, based almost solely on the intuitive notion of action, and this prior to Newton's laws of motion (Viennot, 1996; Tiberghien et al, 2009). This generally does not give learners a Newtonian understanding of this physical entity. In order to get them to understand that it is Newton's second that gives the quantitative definition of the quantity force, Maron and Colin (2016) exploited epistemological aspects by starting from the distinction made by Aristotle and Galileo between "natural movements and violent movements" (Sagaut, 2008) to introduce force as what makes it possible to explain the difference between these two types of movement. This also enabled them to justify that the central element common to falling motion and Newtonian gravitation is the Earth.

This view can be justified by the fact that D'amore et al (2008) have shown that there is a close relationship between the teacher's epistemological conceptions and certain characteristic elements of the discipline. They also managed to show that "the absence of an adequate epistemological culture risks distancing the teacher from the objectives of didactics" (D'amore et al, 2008). As a result, the teaching of physics will be reduced to the dissemination of a non-coherent set of concepts with no effective didactic purpose.

In examining the understanding and models underlying the reasoning of student teachers and high school students, Saglam-Arslan and Devecioglu (2010) found significant weaknesses in understanding the fundamental knowledge terms of Newton's laws of motion, particularly among student teachers. When they went on to explore some of the causes of these weaknesses, they came to the conclusion that this finding is due to the fact that Newton's second law of motion is generally linked to theoretical knowledge rather than to everyday applications.

The knowledge involved in appropriating Newton's second law is not just quantitative, but also qualitative. In relation to the latter, Reif and Allen (1992) and Shaffer (1993) have also noted difficulties on the part of students and even some experts with qualitative questions relating to the nature of the acceleration vector and its schematization in given situations.

If there are so many anomalies from the teachers' training programme to their reasoning when applying Newton's laws in problem-solving situations, then the difficulties identified in research on the learners' side are just as many and multifaceted.

In view of all the above, our aim in this study was to explore physics teachers' knowledge of the epistemology of their discipline and its scholarly and institutional functioning.

3.1. Research question and hypothesis

The teaching of an object of knowledge belonging to a disciplinary field presupposes prior knowledge of this discipline and of the content of this object by the teacher. The object of knowledge in question in this study is Newton's second law, belonging to the disciplinary field of Newtonian mechanics, which is part of physics as a discipline. So we asked ourselves the question: do the physics teachers in our final year classes have the necessary knowledge of the epistemology and the scholarly and institutional functioning of the discipline in relation to Newton's second law?

3.2. Our research question will be put to the test by putting forward and testing the following hypothesis.

All the teachers interviewed for this study had received basic academic and professional training for the teaching profession, and more specifically for their subject. Given the number of years that each of them had spent in the profession, the knowledge gained through training should, in principle, be added to the knowledge gained through experience, thus facilitating practice. This is why we hypothesis that: thanks to the knowledge acquired through training and experience, physics teachers have sufficient knowledge of their subject and its scholarly and institutional workings in relation to Newton's second law in the final year of secondary school.

4. Methodology

4.1. Data collection and corpus composition

This study took place in the department of Borgou, located in the northern part of Benin. It is an attempt to explore certain categories of knowledge of physics teachers, more specifically knowledge of disciplinary content. Thus, for the constitution of our corpus, we proceeded to semi-directive interviews with teachers of Physics, Chemistry and Technology (PCT) intervening in the classes of scientific terminale. This level was chosen because the subject on which this work is based is taught in the final year of secondary school. In order to ensure that these teachers have received the necessary basic training, both academically and professionally, so that they can practise their profession easily and efficiently, we chose to interview certified teachers of the subject in a classroom situation in the final year of secondary school. We interviewed a total of six (06) teachers, including two educational advisors. Of these teachers, two (02) are in service at the Lycée Mathieu Bouké, one at the General Education College Zongo and one at the Collège Privé Académia, three establishments located in the heart of the city of Parakou. The other two are in service at the Prytanée Militaire de Bembèrèkè, a sub-regional school for young soldiers located around a hundred kilometres from Parakou in the northern Borgou region.

In order to conduct these interviews, we drew up a questionnaire with nine (09) questions relating to subject content knowledge. The interviews with the six (06) teachers were audio recorded and transcribed in full. The corpus to be analysed is made up of all these transcriptions.

4.2. The data processing and analysis method.

This article is purely qualitative research. To analyze the corpus obtained from the transcripts of the interviews, we first drew up indicators of expected response elements to serve as references when analyzing the data. For each question, the responses of the six teachers were compared with the references developed for this purpose. From the comparison of the answers given by the teachers with those we produced, we noted whether or not there were any discrepancies or similarities. These are then analysed and discussed to see whether or not they enable learners to learn the subject effectively, and consequently Newton's second law.

5. Analysis And Interpretation of Survey Results

From an epistemological point of view, before defining the contours of a discipline, it must first be possible to define it. None of the teachers (P1, P2, P3, and P4) interviewed was able to offer us an acceptable definition of physics as the discipline they teach. They were therefore completely unaware of the dominant syntactic structures of the definition of physics. On the other hand, the pedagogical advisors made commendable efforts, especially CP2. "...it's a natural philosophy, a philosophy of nature which goes through what, which goes through the interpretation and analysis of natural phenomena and sometimes we exploit formalism to achieve the objectives."

"Physics in a down-to-earth way is the science of matter, the science that studies matter and its properties, interactions and energies".

In the two educational advisers' attempts to define physics, the properties of space and time are obscured, as is the establishment of laws that account for the facts of nature. The definition of the subject being taught was not well understood by the supervisors, the educational advisers, and not at all by the other teachers. Furthermore, no subject can develop without clear objectives. As far as the latter are concerned, physics as taught does not pursue exactly the same objectives as learned physics.

On the question of the objectives of learned physics, teacher P1 stated: "...they enabled us to have theorems because today the theorems that we apply to solve certain problems..." (P1-20). Teacher P2 stated that "The aim of learned physics was to discover the principles that have governed the physical phenomena of life since ancient times". (P2-24). While P1 saw only the establishment of theorems as the sole objective of learned physics, P2 went a step further and spoke of the discovery of the principles governing physical phenomena. It's just that this is not yet acceptable. On the other hand, teacher P3 was unable to address any of the objectives of scientific physics. This is evidenced by his statement: "Yes, the aims of scholarly physics are of course to train quality learners, so in that area". (P3-16). This teacher knew nothing about the objectives pursued by scholarly physics. As for teacher P4, the aims of scholarly physics were "to improve the quality of human life and to explain phenomena that until then might have seemed strange for us". These teachers had little or no knowledge of the objectives, from the outset, of the subject they were teaching. The educational advisers have some knowledge of the objectives of learned physics: "Ah, learned physics, its objectives are to, it is to explain all phenomena and to approach reality". "The objective of learned physics is, um, to know the laws of nature, the laws that govern interactions, physical phenomena that can explain facts, um, to base oneself on these laws in order to be able, um, in their applications, to explain facts or give an opinion on certain situations in life".

These CPs are part of the teaching staff. However, they do not have a good understanding of the objectives of scholarly physics, from which derive those of the subject they are supposed to teach. Under these conditions, what will become of the objectives of the physics taught?

On this question, according to teacher P1, it was so that pupils could take charge of their own lives after leaving school and so that the physics they had learned would help them in their daily lives. For teacher P2, on the other hand, it was more a matter of teaching children the principles they had already acquired through learned physics. Teacher P3 felt that it enabled him to gain qualifications and behave well in society.

For this teacher, physics is taught in our collèges and lycées solely for certification purposes and as models of behavior to be adopted in society. Teacher P4 thought that the aim of the physics taught was to transpose learned physics so as to enable pupils to go further. However, the real reasons for this transposition and what he meant by "going further" remained unknown. CP1 agreed with P4, seeing it as a didactic transposition, which he explained in the following terms: "it's a kind of simplification of learned physics without betraying it". According to CP2, the aim of the physics taught is to make learners understand the laws of nature so that they can use them in practical life. We can say that CP2 has a little more understanding of the objectives of the subject he teaches, unlike CP1 and the other teachers interviewed. These teachers have little or no knowledge of the objectives of the subject they teach. Under these conditions, what knowledge do they have of how physics works to achieve its objectives?

For P1, the function of physics is rather "...to lead pupils to construct their own knowledge..." (P1-26). He also confuses the discipline with a pedagogical approach. This is evidenced when he states in his attempted response: "...the actual discipline itself is the APC...". The competency-based approach is not a disciplinary approach but rather a pedagogical one. He therefore knew nothing about how the physics he claimed to teach worked. As for P2, he confuses the objectives with the way physics works. The proof of this is that, with regard to the functioning of the discipline, he let us understand in his statements: "... the aim, in particular, is to be able to teach learners these principles, as well as enabling them to put them to the test, by taking account of the physical facts, their daily lives, i.e. the realities in which they live".

P3, for his part, declares: "... so to achieve your objectives I think the discipline um works let's say for good according to levels so we try to give them the lessons they need so they can achieve their objective."

We can read in these statements a kind of substitution of a part of the teacher's practices for the way physics works. For P4, it comes down to experiments, as he tells us : "... we have said that MDT is an experimental science, so in order to achieve the objectives, the course is done, experiments are also necessarily needed because we keep more what we have done or what we have seen done than what we have heard."

This gives the impression that for P4, in physics, the experiments are detached from the course. If this is the case, what use are these isolated experiments going to be for the lesson? We can safely say that these four teachers, fully in the classroom, have no knowledge whatsoever of the workings of the subject they teach. Let's take a look at the two educational advisers' understanding of this aspect. According to CP1, physics works according to laws, theorems, principles and properties. All these elements belong to the theoretical world. So, according to him, the way physics works is confined to the theoretical world. As for CP2, for the discipline to achieve its objectives, it has to be taken seriously and taught well. He therefore knows nothing about how the physics he teaches works and how he is supposed to help the other teachers to do their job properly.

Since these teachers are all in a classroom situation, we can ask them the following question: what approach to studying physics do they use in their classroom practices?

For P1, the study approach "is practice". In P2's statements, we note: "...the approach is to help the pupil to discover the principle for himself on the basis of facts or well-situated contexts...". While these two teachers knew nothing about the study approach specific to physics, P3 confused it with the skills-based approach, i.e. with a pedagogical approach. With regard to the question, after a short reflective pause, P4 had this to say: "...I can talk about observation, experimentation and analysis of the results of experiments or observations". We can say that P4 has some knowledge of the hypothetico-deductive approach, even if it is still evasive.

CP1 spoke sometimes of the scientific approach and sometimes of the experimental approach, with some confusion in the explanations: "...the scientific approach is a bit different from the experimental approach because an experimental approach is used to verify a plausible hypothesis, but the scientific approach is not...". According to CP1, this suggests that in a scientific approach there is no hypothesis to be verified by experimentation. In his explanation, CP2 tells us: "... overall it's the scientific approach but we can go into more detail, there's the experimental approach, the technological approach, it depends on the objective". He adds that the most appropriate approach is experimental. When we asked for a little more detail about these approaches, this is what he told us: "Yes, the experimental approach is very much focused on explaining a fact or a phenomenon, but when it comes to designing an object or making an object or using an object or repairing an object, the technological approach is more appropriate, that's the difference between the two". Despite these explanations, the difference in the stages of these two approaches is not mentioned. In addition, there is a confusion between a fact and a scientific phenomenon.

Teaching a subject presupposes mastery of certain basic elements. Among these elements, we were particularly interested in the physical concept, the physical fact, the physical principle and the physical theory. None of the teachers (P1, P2, P3 and P4) was able to provide us with even an approximate definition of any of these concepts. They therefore do not have a basic knowledge of these concepts in physics.

For CP1, "a fact is like a kind of observable phenomenon, an observable phenomenon is a fact". As far as he was concerned, he said: "a principle is an assertion that cannot be demonstrated scientifically, a principle is an assertion that cannot be demonstrated scientifically". Although this definition is the result of an effort at scientific reflection, it is not yet accurate. With regard to the other two concepts, he did not propose any concrete definitions. CP2 defines a physical concept as "a representation based on physics". In relation to the physical fact, it was only the example of the rainbow that he was able to give, so there was no definition. According to him, a physical principle is "...a demonstration adopted as it is and which is a little different from the physical theory...". Moreover, in his explanation, he also referred sometimes to an axiom and sometimes to a prescription, without giving any further details. Although he spoke of the difference between the principle and the physical theory, he made no concrete proposal for a definition of the latter.

The study or application of Newton's second principle in the final year of secondary school involves certain concepts, facts, principles and physical theories. When it comes to presenting them, here's how each of these teachers managed.

P1 confused not only the conditions of applicability of the law and the concepts involved, but also the physical quantities to be determined in a problem and a physical fact: "well, the facts that allow us to use Newton's second law are the quantities that we are asked to determine...". As for the theory involved in this law, he replied that he had no idea. P2 was also unable to give any examples of the concepts involved in Newton's second law. With regard to the physical facts whose explanation or interpretation requires the use of the said law, he mentioned gravitation, uniformly varied rectilinear motion and circular motion. He also confused the prerequisites for applying the law with the physical principles involved. For this teacher, physical theory is equivalent to the development of principles. P2 only masters the physical phenomena that constitute the areas of application of the aforementioned law. In answer to the question, P3 mentioned the concepts of acceleration, speed and the movement of solids as facts, but without any structuring. On the subject of physical principles and theories, we noted an absence of concrete proposals on his part. Teacher P4 did not make any response proposals on this question. Even when it came to concepts, he finds difficult to give an immediate answer".

In his attempted response, CP1 mentioned the fundamental principle of dynamics and how a body falls freely. As far as the concepts were concerned, he proposed those of centre of inertia and equilibrium. The only thing was that he was unable to give us any concrete proposals on the notion of theory. CP2 gave as an example of a concept that of a Galilean frame of reference and a solid in motion in a Galilean frame of reference as a physical fact. But for him theory is equivalent to the formula of the centre of inertia theorem and the principle is equivalent to adopting the formula. Overall, the educational advisers had a few more ideas on the subject than the other teachers (P1, P2, P3 and P4), but still not enough.

Still on the subject of subject content, we wanted to know how each of these physics teachers could explain the concept of gravitation.

For P1, gravitation is the movement of a satellite around the earth or something else. P2 explained the concept of gravitation by the fact that there is an inter-force between two objects of non-zero mass. Continuing his explanation, he added: "...gravitation is the fact that one can revolve around the other or the two can reciprocally revolve around each other... We note that he did not explicitly highlight the phenomenon of attraction between two bodies. P3 also explains the notion of gravitation through the movement of satellites. In his explanation, P4 tells us: "The notion of gravitation is good I'll talk about the movement of stars in relation to others or in relation to the Earth...".

None of these four teachers were able to emphasise in their explanation that this is a natural phenomenon of attraction between two bodies of non-zero mass. So they don't have a good grasp of this concept.

Let's take a look at what the educational advisors have to say. For CP1, "gravitation is the interaction between two bodies with mass". An interaction can be attractive or repulsive, but in the case of gravitation, it is only the former. CP2, in his reply, came to the conclusion: "...it's the attractions, the interactions between bodies". We can say that CP2 is a little more precise than CP1 because of the use of the term "attraction".

We also wanted to know what, according to the teachers interviewed, the relationship $\sum \vec{F}_{ext} = m\vec{a}_G$. For P1 and P3, this relationship translates the centre of inertia theorem. Completing his answer, P3 adds that it is Newton's second law. In his attempt to explain, P2 wanted to give us the statement of the centre of inertia theorem, but only because his explanation was not structured. On the other hand, P4 didn't say anything concrete in his speech-response about the said relationship.

For CP1, this formula expresses the proportionality between energies and movements, i.e. "one energy corresponds to one movement". So, he didn't know what this logical-mathematical relationship meant. As for CP2, "it translates Newton's second law, the theorem of the centre of inertia". In his opinion, Newton's second law is still equal to the centre of inertia theorem, from every point of view. It therefore appears that CP2 joins P3.

6. Research Results and Discussion

Before being operational, pedagogical knowledge is based on disciplinary content. This includes the definition of the discipline, its epistemology and the related conceptual fields.

None of the teachers (P1, P2, P3 and P4) was able to sketch out a definition of physics as the discipline they teach. This means that these teachers have no knowledge of the dominant syntactic structures of the foundations (Nguessan, 2016) of the definition of physics. Even the pedagogical advisers who sketched out answers did not achieve good results. In these cases, it will be difficult for them to have a good grasp of the epistemology underlying the discipline. This is precisely what is confirmed by the results of the questions relating to the aims of learned physics and of the physics taught in class when these teachers have not said anything concrete about it. The problem then arises of a lack of orientation towards efficient teaching of the subject (Rosidah and Zaki, 2022). This can be seen clearly in the answers to the questions about how the subject works and how it is studied. If teachers of the subject do not even know how the subject works between the real and theoretical worlds through the use of models, then they will also not know that they need to use an inductive approach in their practice, moving from the real world to the theoretical world with feedback.

Newton's second law is developed in relation to a conceptual field (Vergnaud, 1990), certain key terms of which should be appropriated by teachers. This is the case, for example, with a physical concept, a fact specific to physics, a principle and a physical theory. When it came to proposing definitions for these terms, these teachers were unable to provide good answers that could demonstrate a degree of mastery. Only P3 and the CPs tried to give a few examples. Under these conditions, we are tempted to say that they do not have a good understanding of the basic elements of the conceptual field to which the law whose teaching is the subject of this research work belongs. One of the questions we can ask ourselves in view of this observation is: how will they manage to mobilize the concepts needed to develop adequate conceptual maps around the dominant terms of the law during its teaching in order to promote its proper appropriation by the learners?

The notion of gravitation and the logical-mathematical relationship modelling the centre of inertia theorem are not well understood by the CPs and other teachers, even though these two concepts highlight not only the interactions modelled by the concept of force (attractive in the first case, attractive and/or repulsive in the second) but also the concept of mass. One of the consequences of not mastering the concept of gravitation and what is expressed by the relation $\sum \vec{F}_{ext} = m\vec{a}_G$is that the teachers will have difficulty making the difference between gravitational mass and inertial mass in order to make good use of it in interpreting the movement of bodies.

The official texts represent, as it were, the teacher's compass through their recommendations. In the context of the physics, chemistry and technology syllabuses currently in force, the recommendations in these texts do not take into account the fact that the subject operates between two worlds (real and theoretical) through the use of appropriate models, something that these teachers do not know how to take into account in their teaching. These epistemological and didactic gaps can lead to a cacophony of teaching practices, further distancing the teaching of the subject from its objectives.

7. Conclusion

Physics is one of the teaching disciplines whose applications contribute enormously to the harmonious and sustainable technological development of a nation. Students' recurrent lack of interest in this subject due to repeated failures prompted us to conduct this research on physics teachers' knowledge of subject content. The results of the semi-structured interviews with these actors are alarming. Physics teachers who have no mastery of the epistemology of their subject, its scholarly and institutional functioning in relation to Newton's second law. They will find it difficult to gear their teaching towards effective learning of the subject through its objects of knowledge and, more specifically, Newton's second law. There is therefore an urgent need to review the content of teacher or student teacher training programs to enable physics to easily achieve its objectives by means of the following.

Compliance with ethical standards

Disclosure of conflict of interest

All the authors acknowledge that there is no conflict of interest. They all agree with what is written in this article. In accordance with the requirements of transparency and scientific integrity, we, the authors of this study, declare that we have no conflict of interest, whether financial, commercial or otherwise, that could influence the results or interpretations of our research on initiation rites in Benin, thus guaranteeing the independence and objectivity of our work and ensuring the credibility of our conclusions.

References

[1] Abell, S. K. (2007). Research on science teacher knowledge. In Handbook of Research on Science Education Eds : Abell, S. K. and Ledeman, N. G. Lawrence Erlbaum Associates Inc.

[2] Cariou, J. Y. (2011). Histoire des démarches en sciences et épistémologie scolaire. RDST – Recherche en didactique des sciences et des technologies, no3, pp. 83-106.

[3] Chevallard, Y. (1985). La transposition didactique à l'épreuve. La Pensée sauvage.

[4] Dachraoui, S., Taqi, A., Ait, B. K., Hassouni, T., Al Ibrahmi, E. M. (2023). Formation interdisciplinaire mathématiques-sciences physiques des futurs enseignants de physique chimie. Laboratoire de Recherche Société, Langage, Art et Médias, vol.9 n°9.

[5] D'Amore, B., Fandino Pinilla, M. I., Marazzani, I., Santi, G., Sbaragli, S. (2008). Le rôle de l'épistémologie de l'enseignant dans les pratiques d'enseignement. Atti su DVD del colloque international (con referee) : " Les didactiques et leurs rapports à l'enseignement et à la formation. Quel statut épistémologique de leurs modèles et de leurs résultats ?". 18, 19, 20 septembre 2008. Bordeaux (Francia), Università Bordeaux 4

[6] Durandeau, J. P., Bigorre, M., Bramand, P., Dulaurans, T., Faye, P., Poudens, B. (2006). Physique Terminale Scientifique. Hachette livre, 43, quai de Grenelle, F 75905 Paris Cedex 15.

[7] Duval, R. (1993). Registres de représentation sémiotique et fonctionnement cognitif de la pensée. Annales de didactique et de sciences cognitives, vol 5. Pages 35-61.

[8] Grossman, P. L. (1990). The making of a teacher : teacher knowledge and teacher education. Teachers College Press.

[9] Maron, V., Colin, P. (2016). Comment justifier la notion d'attraction terrestre ? Apports épistémologiques d'une reconstruction conjointe de la dynamique et de la gravitation newtoniennes. 9è rencontres scientifiques de l'ARDiST-30, 31 mars et 1er avril, LENS.

[10] Laugier, A., and Dumon, A. (1998). Enseigner les sciences physiques avec de jeunes élèves : Quelle épistémologie pour quelle démarche ? Bulletin de l'Union des Physiciens, no806, vol 92, 1257-1278.

[11] N'Guessan, D. (2019). Philosophie des sciences physiques : Classification des sciences et axes de recherche en l'épistémologie des sciences physiques. Université Félix Houphouet-Boigny. UFR SHS, Département de Philosophie. Licence 2.

[12] Nguessan, K. (2016). Les Lois de Mouvement et les Théorèmes en Mécanique Classique. Repérage de Quelques Difficultés et Obstacles Chez les Étudiants en Formation Professionnelle. Canadian Social Science, 12(1), 59-68.

[13] Oké, E., Kanffon, A., Kelani, R. R. (2019). Exploration des conduites d'élèves lors de la mise en œuvre de la deuxième loi de Newton en terminale scientifique au Bénin. Liens no27, volume1, 38-54.

[14] Paty, M. (1998). La philosophie et la physique. Jean-François Mattéi. Le Discours philosophique, volume 4 de l'Encyclopédie philosophique universelle, Presses Universitaires de France, p. 2104-2122.

[15] Reif, F. and Allen, S. (1992). Cognition for interpreting scientific concepts: study of acceleration, Cogn. Instruction 9, 1– 44.

[16] Rosidah, S., Zaki, A. (2022). The Pedagogical Content Knowledge (PCK) of Prospective Teachers. Journal of Education and Learning Innovation. Vol. 2 no4. https://doi.org/10.35877/454RI.eduline1291.

[17] Sagaut, P. (2008). Introduction à la pensée scientifique moderne.Université Pierre et Marie Curie – Paris 6 http://www.ampere.cnrs.fr/histoire/parcours-historique/unites-electriques/histoire

[18] Saglam-Arslan, A. and Devecioglu, Y. (2010). Student teachers' levels of understanding and model of understanding about Newton's laws of motion. Science Learning and Teaching, volume 11, Issue 1, Article 7, p.2

[19] Shaffer, P. (1993). ''The use of research as a guide for instruction in physics,''Ph.D. dissertation, Department of Physics, University of Washington.

[20] Shulman; L. S. (1986). Those who understand : knowledge growth in teaching. Educational Researcher, 15(2), 4-14.

[21] Shulman; L. S. (1987). Knowledge and teaching : foundation for a new reform. Harvard Educational Review, 51(1), 1-22.

[22] Tiberghien, A., Vince, J. and Gaidioz, P. (2009). Design Based Research, Case of a teaching sequence on mechanics. International Journal of Science Education, 31(17), 2275-2314.

[23] Tomasino, A., Gendreau, B., Parent, C., Patrigeon, F., Simon, C., Horn, M. (1999). Physique Terminale scientifique. Editions Nathan, 9,rue Méchain 75014 Paris ISBN 209-172 207-3.

[24] Vergnaud, G. (1990). La théorie des champs conceptuels, Recherches en Didactique des Mathématiques, vol.10 n°2-3, 133-170.

[25] Viennot, L. (1996). Raisonner en physique. La part du commun. De Boeck.