

## Pedagogical curriculum approach about Momentum, Impulse of a Force and Newton's Laws for a scope of integrated High School

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**Abstract:** In this investigation, we aim to comprehend the proposition of a pedagogical curriculum approach for teaching action in Physics in a integrated high school while scientific knowledge is built by students from Newton's Laws. We appropriated the qualitative approach of research that culminated in the argumentation of bibliographic productions by the last five years (2017-2022), and also a theoretical-practical construct for teaching action through structures, analysis and evaluative procedures to teachers. These results indicate an scarcity of discussions about this theme with articulated proposition for integrated high school, which emphasizes the potentiality/dynamicity of the material produced, adaptable to pedagogical needs and to scopes of scientific learning.


**Keywords:** Physics Curriculum. Pedagogical Curricular Approach. Newton's Laws. Integrated High School.


### Enfoque curricular pedagógico sobre Cantidad de movimiento, Impulso de una Fuerza y Leyes de Newton: forjado para el contexto de la Escuela Secundaria Integrada


**Resumen:** En esta investigación, pretendemos comprender la proposición de un abordaje curricular pedagógico para la acción docente em Física en la Enseñanza Media Integrada en el momento en que el conocimiento científico es construido por los estudiantes a partir de los estudios de las Leyes de Newton. Nos apropiamos del abordaje cualitativo de la investigación que culminó en la argumentación de producciones bibliográficas en el campo del tema de los últimos cinco años (2017 - 2022), además de un constructo teórico-práctico para la acción docente, a través de estructuras, procedimientos de análisis y evaluación para el docente. Los resultados apuntan para la escasez de discusiones sobre el tema con una propuesta articulada para la Educación Secundaria Integrada, que refuerce la potencialidad/dinámica del material producido y adaptable a las necesidades del aprendizaje pedagógico, así como a los contextos de aprendizaje científico.

**Palabras clave:** Plan de Estudios de Física. Enfoque Curricular Pedagógico. Las Leyes de Newton. Escuela Secundaria Integrada.

### Abordagem curricular pedagógica sobre Quantidade de Movimento, Impulso de uma força e Leis de Newton: forjadas para o contexto do Ensino Médio Integrado

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**Resumo:** Nesta investigação, visamos compreender a proposição de uma abordagem curricular pedagógica para a ação docente em Física no Ensino Médio Integrado ao tempo que o conhecimento científico é construído pelos estudantes a partir dos estudos das Leis de Newton. Apropriamo-nos da abordagem qualitativa da pesquisa que culminou na argumentação de produções bibliográficas no campo da temática dos últimos cinco anos (2017-2022), além de um constructo teórico-prático para ação docente, por meio de estruturas, análise e procedimentos avaliativos ao professor. Os resultados apontam para a escassez de discussões da temática com proposição articulada para o Ensino Médio Integrado, o que reforça a potencialidade/dinamicidade do material produzido e adaptável às necessidades de pedagógicas, bem como aos contextos de aprendizagem científica.

**Palavras-chave:** Currículo de Física. Abordagem Curricular Pedagógica. Leis de Newton. Ensino Médio Integrado.

## 1 Starting formative dialogues

In the last decades, we have experienced profound and significant changes on the curricular scenario of Physics teaching in Integrated High School, a formative space where we have been working for more than 10 years, with signs from impacts of new formulations into the national base until pedagogical practices that require many teaching skills to achieve a new learning overview.

More recently, the approval of the Common National Curricular Basis — CNCB (BRASIL, 2018) brought a series of questions for teachers didactic action, because many of them are unassisted on how to put into practice what CNCB shows as theory.

From reviewers to defenders, we do not take a stand as allies of these movements, but as teachers and researchers who work in a context of teaching, research, and extracurricular activities of Science Education and in its theoretical and methodological assumptions.

By considering those questions we tackle the following one: how does a pedagogical curricular approach enable the Physics teacher's action in Integrated High School and the construction of the students' scientific knowledge, at the same time that concepts/knowledge are articulated based on Newton's Laws?

This question is understood as a compass that guides us into the investigative process and makes it possible to directly discuss the Physics curriculum in Integrated High School, since we work in institutions that offer technical courses in this modality, and it firstly unfolds in a bibliographical survey about the theme and the proposition of a theoretical-practical construct for the classrooms.

We can understand that discussion about the Physics curriculum in Integrated

High School is not a recent issue, but it has corroborated other discussions in the area by several researchers (CARVALHO and VANNUCCHI, 1996; OSTERMANN and MOREIRA, 2001; CHIQUETO, 2011) and it still deserves special attention for teaching practice.

We elected as objective of this investigation to comprehend the proposition of a pedagogical curricular approach for teaching action about Physics in Integrated High School while scientific knowledge is built by students from Newton's Laws.

Educational research, within the area of curriculum for teaching Physics, has demonstrated an importance of promoting an education for citizenship, as well as favoring democratic participation and critical thinking of our students.

In this paper, we present a pedagogical curriculum approach resulting from our experiences as teachers and researchers in the area, in order to enable new perspectives on the Physics curriculum in Integrated High School and our pedagogical constructions developed for classroom practice.

## **2 Methodological guidelines: the parts and the whole of the investigation**

Given the objective for this investigation, we intend to comprehend our pedagogical practice and take a new look at the construction of scientific knowledge, since we use the theoretical and methodological framework of a qualitative research (DESLAURIERS, 1991) for direct observation of our lived experience as Physics teachers in an Integrated High School.

Qualitative approaches become us more familiar with our own practices, perceiving ourselves as active subjects in teaching, and allow us to reflect on our didactic, pedagogical, and epistemological concerns about students' scientific learning, as well as they make it possible to produce fresh information.

Initially, we bring up here the bibliographical research (LAKATOS and MARCONI, 2003) as a way to review written academic productions, not being here a mere repetition of what has already been produced, but a way to propitiate the theme with new discussions about what we propose, showing subsidies for knowledge and perspectives for investigation.

In this way, the investigation manages the spatial-temporal process of the bibliographic production, for which we deepen, indicate and delimit the variables with

selected descriptors, as well as we explore the reflections from the empirical content.

With the proposition of pedagogical curricular approach, we use the theoretical frameworks of DBR-TLS (Design Based Research and Teaching-Learning Sequences), since we follow the DBR foundations as established by Brown (1992), Collins (1992) and DBR Collective (2003), and TLS according to Lijnse (1995) and Mèheut and Psillos (2004).

Elaborating a pedagogical curriculum approach by DBR-TLS goes beyond a simple didactic proposition, as it involves: (i) a pedagogical material that makes it possible to diversify the teacher's practice in classroom; (ii) to bring up a content that appreciates the Physics curricular update in Integrated High School, in order to attend the students' learning needs; (iii) to present a set of propositions that can be adapted to a school context, according to the educational reality in which the subjects are inserted.

The assumed theoretical and methodological references guarantee quality to the investigation and allow the classroom pedagogical interests to be placed in relevance, at the moment the teacher mediates the scientific knowledge so that the students build it into an autonomous and critical way.

### **3 (Re)thinking about action: strategies for Physics teachers' practice**

Our pedagogical reflections start when we try to understand how the theme has been discussed in the academic sphere for pedagogical practice, and later we bring a proposal for curriculum organization based on our own experiences.

In this way, the arguments presented here reiterate: (a) a bibliographical survey based on academic productions of the last five years, with the aim of corroborating the proposal that we have developed in the classroom, and subsequently, (b) a pedagogical curricular approach resulting from our experiences as Physics teachers from theoretical and methodological assumptions that we have taken on as researchers.

#### **3.1 Study on bibliographic productions: academic mapping of the last half decade**

Before we discuss about our pedagogical experiences as Physics teachers in Basic Education and in Higher Education, it is salutary that to understand what has

been produced by other researchers in Brazil.

Thus, we have chosen to outline, as data/results argumentation in this research, the mapping performed on bibliographic productions of the last half decade in the field of this theme we are expose, in order to comprehend and corroborate the proposal we have been developing in the classroom.

We visited the Google Scholar portal because we understand that it is fed by researchers as well as by journals and institutional repositories themselves, which allows us to identify productions in the most different knowledge areas.

This enhances the discussion here, as it transits the field of Teaching and Education, mainly, about what would demand or make the search difficult if we were to resort to specific journals, for example.

Therefore, we searched the portal for productions from the last half decade (2017-2022), considering only results in portuguese (Brazil), using descriptors like "curriculum", "physics teaching", "high school", "Newton's Laws", "impulse of a force" "momentum" and "skills and abilities" that make up our object of study.

From this recursive procedure, we obtained 29 results, distributed as follows: 15 master's dissertations (of these, the link of one dissertation did not open and we could not access the dissertation portal of the institution, and the other one was from Portugal), 01 doctoral thesis, 01 work published in event annals, 04 undergraduating conclusion papers, 01 instructional material, 04 pedagogical course projects, 01 discipline program and 02 guiding documents.

From this survey we chose, by inclusion criteria, to discuss only the master's dissertations and the doctoral thesis that argue about the theme (Chart 1).

Chart 1: Bibliographic survey on the research theme in theses and dissertations (2017-2022)

Publication year	Headline	Authors	Institution
2017	O currículo da disciplina de Física: compreensão de um grupo de professores da rede estadual de ensino do estado de São Paulo [Curriculum of Physics discipline: comprehension of a teachers group in the State of São Paulo's education system]	Alexandre Afranio Hokama Silva	UNINOVE
2018	Caracterização dos trabalhos de dissertações de mestrado na área de ensino de astronomia defendidas no mestrado nacional profissional de ensino de Física	Fabiana Gozze Soares	UNIFEI

	[Characterization of dissertations in astronomy education presented in the national professional master's degree in Physics education]		
2018	A taxonomia de Bloom aplicada à questões de Física [Bloom's taxonomy applied to Physics issues]	Maurício Paulo Rodrigues	UFV
2018	Análise da matematização da Física na concepção dos professores de Física do IFBaiano - Guanambi [Analysis of Physics mathematization by conception of Physics teachers from IFBaiano – Guanambi]	Eric Novais Silva	UESB
2018	Física no trânsito: uma abordagem com enfoque ciência, tecnologia e sociedade em Santarém-Pará [Physics in traffic: an approach focusing on science, technology and society in Santarém-Pará]	Márcio José do Carmo Soares	UFOPA
2018	Proposta de ensino de Física em espaço não formal: uma aula de mecânica no parque de diversões [Physics teaching proposal in a non-formal space: mechanics class at the recreational park]	Fábio Henrique de Sousa Chagas	UnB
2019	Inércia e a 1ª lei de Newton: potencialidades de uma sequência de ensino investigativa [Inertia and Newton's 1 <sup>st</sup> law: potentialities of an investigative teaching sequence]	Wellington Sampaio Ribeiro	UnB
2019	A Olimpíada Brasileira de Física das Escolas Públicas como instrumento de aprendizagem [Brazilian Physics Olympics for Public Schools as a learning tool]	Ronaldo Cristiano da Silva Moura	UFAL
2019	O uso de website no ensino e aprendizagem de termometria [Use of websites in teaching and learning about thermometry]	Fabício Rodrigues Alves	UFPA
2019	Estudo das transformações de energia em uma abordagem CTSA [Study of energy transformations by a STSE (Science, Technology, Society, Environment) approach]	Mateus Natálio Soares do Nascimento	IFES
2020	Física no Ensino Médio em escolas públicas de Teófilo Otoni (MG): estudo comparativo de duas coletâneas de livros didáticos de Ciências da Natureza/Física, adotadas para o período de (2016 a 2020) [High School Physics in public schools of Teófilo Otoni, MG: comparative study of two collections of Natural Sciences/Physics textbooks adopted for the period from 2016 to 2020]	Luciano dos Santos	UFVJM
2020	Aplicação e análise de uma sequência didática para abordagem de cinemática e teoria da relatividade restrita no Ensino Médio [Application and analysis of a didactic sequence]	Josué Duda	UEPG

	to approach kinematics and theory of restricted relativity in high school]		
2021	Robótica educacional no ensino de Física: construção e aplicação de carrinhos de controle remoto para abordagem do conteúdo de dinâmica - forças e as Leis de Newton [Educational robotics in Physics teaching: building and applying remote control carts to approach the dynamics content - forces and Newton's Laws]	Maicon Teixeira de Matos	UFSC
2022	Lançamento de foguetes pet no contexto do Ensino Médio: um convite para o aprendizado da composição de movimentos e da terceira lei de Newton por um sistema de massa variável [Polyethylene Terephthalate rocket launching in the context of high school: an invitation to learn motion composition and Newton's third law of motion for a system of variable mass]	Paulo Sérgio Prado de Oliveira	UFSCar

Source: Google Scholar (Prepared by the Authors)

In light of this, we have chosen to make reflections and deeper discussions based on these productions because we believe they are built with high scientific accuracy and present all the relevant academic-textual notes for each developed investigation.

On these terms, the research of Matos (2021) presents a proposal about the use of Newton's Laws by a pulley system using educational robotics, highlighting greater motivation and engagement by students in search for solutions when related to momentum, even exploring the relationships between the equations, as announced by Newton.

Ribeiro (2019) explores the study of inertia and makes correlations with momentum, bringing up a study of relationships between forces and motion, and realizing that students are motivated to the process of scientific literacy, which allows us to ensure there are possibilities to work these contents in an articulated way.

Silva (2017) highlights opportunities in the study of Newton's Laws sequenced with analysis of collision and momentum that, despite not proposing an articulation between concepts/contents, it is possible to perceive playful possibilities by the curricular proposition pointed out by trainee teachers in their pedagogical activities, ensuring a freedom of organization and restating that there are possible interrelationships.

Chagas (2018) proposes a Physics teaching activity in a non-formal space and

enables correlations between phenomena that highlight Newton's Laws and quantity of motion, including by discussing momentum by the group activities performed with students in the trip to the park. The author also explores concepts such as velocity and acceleration by the experience developed with students in the formative space.

The other authors do not exactly discuss correlations or interrelations between the contents we propose here; however, the search identified these works for containing the descriptors we have organized. It is not in our interest to say these works do not attend the specific goals performed, but, in fact, they will not be discussed here because they do not attend our inclusion criteria.

On the other hand, we understand the productions are rich and have been very well explored by their authors, with well-defined objectives and well-structured theoretical and methodological references that sufficiently attend the propositions pointed out here as rich material to be explored by more researchers in the area.

Therefore, it is worth mentioning that there is still limited or latent production that discusses the articulation of contents of Newton's Laws, momentum and quantity of motion as initially conceived by Isaac Newton, which corroborates the proposition of this investigation, justifying and contextualizing our pedagogical curriculum approach.

We stress that the studies explored here have potential to be further deepened by researchers and teachers, so that they can be articulated in the classroom and escape from traditional conceptions of the Integrated High School Physics curriculum, which guarantees us more pedagogical versatility and further developing students' critical consciousness (FREIRE, 2009).

This rupture from traditional Physics teaching allows us to get out of our comfort zone, by establishing that relationships between school Physics and everyday life is not a usual practice (RICARDO and FREIRE, 2007), which enables a more consolidated scientific education.

Certainly the pedagogical process of teaching Physics in Integrated High School still endures for many decades as a space of "knowledge transmission", which has generated much estrangement between teaching and scientific learning of the individuals involved, avoiding a reductionist view (CATARINO *et al.*, 2013).

Therefore, as teachers and researchers, we must develop proposals that culminate in innovative ideas that articulate conceptions of curriculum for Physics



teaching, in order to make our pedagogical practice less rigid/stuck and more dynamic for the science education of students.

### **3.2 Pedagogical curriculum approach: a proposal for teaching Physics using DBR-TLS**

We start discussing our pedagogical curriculum approach by recalling that Newton's three laws are understood as postulates governed by nature and not necessarily as a bunch of formulas or concepts proposed for teaching Physics.

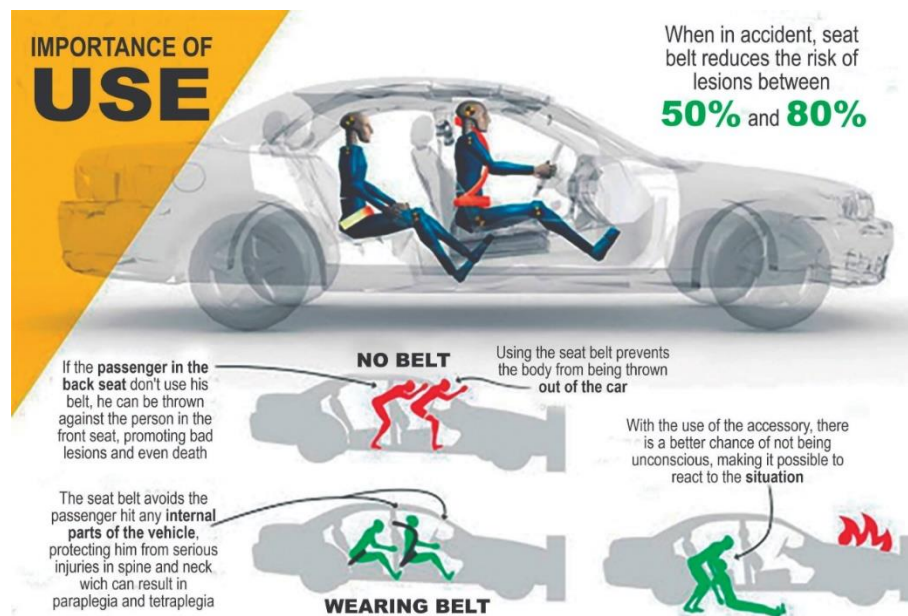
We emphasize these postulates are accepted as true because they are experimental findings. Therefore, they assume a category of physical laws, or in other words, truths manifested by nature itself. Thus, we present a pedagogical curricular approach that will make the form addressed/discussed here possible and considered as a facilitating tool in the teaching and learning process.

It is important to mention that the construction of the pedagogical curricular approach was developed based on theoretical and methodological assumptions of DBR-TLS, which guarantees dynamism to the process and to a pedagogical management of the process into the classroom, as observed in the research conducted by Rodrigues-Moura (2016), when working Particle Physics themes in high school.

We also emphasize that the curricular pedagogical approach covers the contents to be studied previously to Newton's Laws, articulating the concepts inherent to this practice.

To structure an initial problematization of the curricular pedagogical approach, we used an image of alert and traffic education released by DETRAN/RS that highlights the importance of seat belts for vehicle passengers, as shown in Figure 1.

Figure 1: Initial problematization for theme study



Source: DETRAN, Rio Grande do Sul, Brazil<sup>4</sup>

From this problematization, we propose three questions to the students: (1) Do you wear seat belts?; (2) How important is the use of seat belts when we are in moving vehicles?; (3) What are the relationships between seat belt use and our state of movement inside a vehicle?

A wide range of situations was observed, from students who do not use seat belts to those who do not consider its use importante, nor even do not perceive the serious risk of accidents when not used. Some students even mentioned that the use was more related to the situation of the driver not being surrounded when breaking traffic laws.

Phenomena involving Newton's Laws and the Principle of Conservation of Momentum are inserted in our everyday lives: braking a bicycle or activating the airbags of a vehicle to reduce the impacts of a collision upon the driver, or even colliding the cue with a billiard ball when playing pool with friends in a bar, for example.

As much as there is a wide range of situations involving Newton's Laws, we ask ourselves: why are there people who still don't wear a seat belt? Why in Brazil about 32 people die every day in traffic accidents? What can be done in Physics teaching practice in attempt to reduce this sad statistic?

We organized a curriculum pedagogical approach based on the following information in Chart 2, reiterating that we made this planning in mutual collaboration.

<sup>4</sup> Available in: <http://blog.tuningparts.com.br/cinto-de-seguranca-para-passageiros-por-que-usar/>

Chart 2: Planning the pedagogical curriculum approach for teaching Newton's Laws

<b>Subject</b>	Newton's Laws
<b>Grade</b>	2 <sup>st</sup> grade, Integrated High School
<b>General objective</b>	Enunciate and analyze the Classical Mechanics basic laws (Newton's Laws)
<b>Specific objectives</b>	<ul style="list-style-type: none"> <li>- Understand the historical context of the birth of Newton's Laws;</li> <li>- Consolidate the fundamentals of the cause of the movement of bodies (mass, inertia, force);</li> <li>- Correlate Newton's Laws with impulse of a force and momentum in an articulated way;</li> <li>- Identify the applications of Newton's Laws in everyday life;</li> <li>- Analyze this knowledge in the living world, in current equipment and technological procedures.</li> </ul>
<b>Proposed contentes</b>	Introduction to Physics Vectors Quantity of Motion Newton's Laws
<b>Abilities</b>	<p>(EM13CNT204) Elaborate explanations, predictions and calculations regarding movements of objects on Earth, in the Solar System and in the Universe based on analysis of gravitational interactions, with or without the use of digital devices and apps (such as simulation and virtual reality softwares, among others).</p> <p>(EM13CNT207) Identify and analyze vulnerabilities linked to contemporary challenges to which young people are exposed, considering physical, psycho-emotional and social dimensions in order to develop and disseminate actions to prevent and promote health and well-being.</p> <p>(EM13CNT301) Constructing questions, elaborating hypotheses, predictions and estimates by employing measurement instruments and representing and interpreting explanatory models, data and/or experimental results to construct, evaluate and justify conclusions in dealing with problem situations from a scientific perspective.</p> <p>(EM13CNT306) Assess the risks involved in daily activities by applying knowledge from natural sciences to justify the use of safety equipment and behaviors, aiming at physical, individual, collective and socio-environmental integrity.</p> <p>(EM13LGG701) Explore digital information and communication technologies (DICT), understanding their principles and functionalities and mobilizing them in an ethical, responsible and appropriate way for language practices in distinct contexts.</p> <p>(EM13MAT314) Solve and elaborate problems involving composite quantities, determined by the ratio or the product of two others, such as velocity, population density, electrical energy, etc.</p>
<b>Program contente</b>	1) Introduction to Physics: <ul style="list-style-type: none"> <li>- Introduction to natural sciences (exposition of the scientific method);</li> <li>- What is Physics? (definition of Physics science, what is studied in it, main areas of Physics);</li> <li>- Measurement of quantities and measurement units;</li> <li>- Applications in everyday life.</li> </ul> 2) Vectors: <ul style="list-style-type: none"> <li>- Scalar and vector quantities;</li> <li>- Sense and direction;</li> <li>- Vector (definition);</li> <li>- Vector Operations (addition, multiplication of a scalar by a vector);</li> <li>- Vector decomposition;</li> </ul>

	<ul style="list-style-type: none"> <li>- Vectors;</li> <li>- Scalar and vector product;</li> <li>- Technological applications.</li> </ul> <p>3) Momentum:</p> <ul style="list-style-type: none"> <li>- Introduction to translational movements (exposition and discussion of everyday situations involving transfer of momentum);</li> <li>- Momentum (definition);</li> <li>- Conservation of Momentum;</li> <li>- Examples and practical applications in everyday life.</li> </ul> <p>4) Newton's Laws:</p> <ul style="list-style-type: none"> <li>- Historical introduction to Newton's Laws (focus on previous works about motion of bodies, spontaneous conceptions of force and motion, Aristotle's mechanics, Descartes works, Galileo's experiments, presentation of Isaac Newton work);</li> <li>- Discussions and conceptualization of mass, inertia and force.</li> <li>- Statement of Newton's 1<sup>st</sup> Law;</li> <li>- Statement of Newton's 2<sup>nd</sup> Law;</li> <li>- Impulse of a force and Impulse Theorem;</li> <li>- Newton's 3<sup>rd</sup> Law;</li> <li>- Technological applications and uses.</li> </ul>
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Source: Prepared by the Authors

The pedagogical curriculum approach is not necessarily a "recipe" that teachers should follow nor a finished/stuck production, but a construction that results from our experiences as teachers and researchers in Physics teaching, bringing up new perspectives for the pedagogical practice as we have discussed.

### **3.3 Unified comprehension for a construction of Momentum concept, Impulse of a force and Newton's Laws**

Next, we present a suggestion on how a teacher should work on a unified comprehension of the concepts and statements that make it possible to understand the study of Momentum ( $p$ ), the impulse of a force and Newton's Laws.

#### 1<sup>st</sup> Discussion — Statement of Newton's First Law (Principle of Inertia):

We will start with the original Principle of Inertia statement translated from Latin:

*“Every body remains in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by action of applied forces”*

We can state this same law in a didactically more accessible way:

*“Every body persists in its state of rest (static equilibrium), or of uniform motion in a straight line (dynamic equilibrium), unless it is compelled to change that state by action of non-zero resultant forces impressed upon it”*

Already in Newton's first law, it is convenient to associate the momentum to the consequences of this statement. This is a way to prepare the student not only to understand the second law, but also to be faithful to the proposal of a joint construction of knowledge between the quantity of motion and Newton's Laws.

Let's see how this can be done: by defining two forms of equilibrium it is possible to establish that, in static equilibrium, the body has a constant momentum equal to zero (since its velocity is equal to zero). In dynamic equilibrium, this momentum is also constant, but different from zero (since the velocity is constant). In this way, it will be clear to the student that the concept of momentum is between the lines of the Principle of Inertia statement.

2<sup>nd</sup> Discussion — Statement of Newton's Second Law (Fundamental Principle of Dynamics):

We will start again with the original Fundamental Principle of Dynamics statement translated from Latin:

*“Motion variation is proportional to applied driving force and it is given over the direction of the line along which the force is applied”*

If the original statement were presented to the students, it would cause a huge confusion in its understanding and in its conceptual essence, for the terms used at that prior time being very different from terms used nowadays, such as motion variation of movement, which mentions the variation of quantity of motion, and driving force, which refers to the resultant force.

This pedagogical action can become didactically inaccessible. The original form was presented only as a way of proving the existence of the term and the concept of momentum in this law. The teacher could state it in another way, for example:

*“The application of a resultant force on a body will cause its momentum to change in time”*

$$\vec{F}_R = \frac{\Delta p}{\Delta t} (I)$$

The traditional way of teaching Newton's 2<sup>nd</sup> Law is presenting the famous expression  $F_R = m \cdot a$ . However, this form distorts how the Newton's 2nd Law was stated and thought in his work. Furthermore, it does not offer an opportunity to clearly and directly associate the concept of momentum.

It is very didactically convenient to use the original formulation, because from this we can arrive at the concept of impulse (and the module of this quantity is represented as  $IR$ , one of the physical quantities present in equation I) and in the Impulse Theorem (equation II):

$$\vec{F}_R = \frac{\Delta \vec{p}}{\Delta t} \Rightarrow \vec{F}_R \cdot \Delta t = \Delta \vec{p} \Rightarrow \vec{I}_R = \Delta \vec{p} \quad (II) \quad (\text{Impulse Theorem})$$

These expressions are mathematically equivalent for the simple fact that it is possible and trivial to arrive at one of them departing from the other.

### 3<sup>rd</sup> Discussion — Statement of Newton's Third Law (Action and Reaction Law):

The following is the original statement translated from Latin of the Action and Reaction Law:

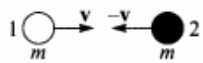
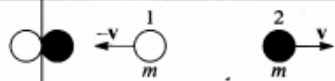
*“To every action there is always opposed an equal reaction; or, mutual actions of two bodies are always equal and directed to their opposite parts”*



The interesting thing here is that we can easily associate the Action and Reaction Law not only with the momentum, but also with the Principle of Conservation of Momentum.

This approach is even found in Physics books for undergraduation, such as “Basic Physics Course 1 – Mechanics” (NUSSANZVEIG, 2013). We are going to transcribe, with necessary adaptations, the line of reasoning to reach the statement of Newton's Third Law by the Principle of Conservation of Momentum.


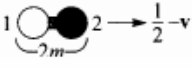
We will start from three experiences, which are:

Figure 2: Initial problematization for study of the theme, based on three experiences involving collisions. In (a) we have Experiment 1: Collision between two balls with opposite velocities; in (b) we have Experiment 2: Collision with a ball at rest; and in (c) we have Experiment 3: Collision with a ball with aggregation after the shock.

Experiência 1			
Antes da colisão		Depois da colisão	
			
Velocidades	$v_1 = v$ $v_2 = -v$	$v'_1 = -v$	$v'_2 = v$
Momentos	$p_1 = mv$ $p_2 = -mv$	$p'_1 = -mv$	$p'_2 = mv$
Total	$P = p_1 + p_2 = 0$	$P' = p'_1 + p'_2 = 0$	

Experiência 2	
Antes da colisão	Depois da colisão
	
Velocidades $v_1 = v$ $v_2 = 0$	$v'_1 = 0$ $v'_2 = v$
Momentos $p_1 = mv$ $p_2 = 0$	$p'_1 = 0$ $p'_2 = mv$
Total $P = p_1 + p_2 = mv$	$P' = p'_1 + p'_2 = mv$

Experiência 3	
Antes da colisão	Depois da colisão
	
Velocidades $v_1 = v$ $v_2 = 0$	$v'_1 = v'_2 = \frac{1}{2} v$
Momentos $p_1 = mv$ $p_2 = 0$	$p'_1 = p'_2 = \frac{1}{2} mv$
Total $P = p_1 + p_2 = mv$	$P' = p'_1 + p'_2 = mv$

Fonte: Nussenzveig (2013, p. 101-102)

We conclude that:

$$p = p_1 + p_2 \text{ (III)} \quad p'_1 + p'_2 = p' \text{ (IV)}$$

Therefore:

$$p = p' \text{ (V)}$$

Momentum in an isolated system of external forces is conserved (conclusion expressed by equations III, IV and V).

Another conclusion from the Principle of Conservation of Momentum is:

$$p'_1 + p'_2 = p_1 + p_2$$

$$p'_1 - p_1 = -(p'_2 - p_2)$$

$$\Delta p_1 = -\Delta p_2 \text{ (VI)}$$

Substituting in (I) in (VI) and considering the duration of the collisions to be equal, we have:

$$F_1 \cdot \Delta t_1 = -F_2 \cdot \Delta t_2$$

$$F_1 = -F_2 \text{ (VII)}$$

Equation (VII) indicates the force exerted by ball 1 on ball 2 ( $F_1$ ) has the same magnitude and direction as the force that ball 2 exerts on ball 1 ( $F_2$ ). The minus sign

refers to the opposite directions of F1 in relation to F2. This conclusion, therefore, is known as Action and Reaction Law (Newton's 3rd Law), commonly stated as:

*“Every action generates a reaction, in same magnitude and direction, but in opposite senses”*

### **3.4 Possibilities for evaluation of the pedagogical action on scientific learning**

For the evaluation of Physics learning from the proposed curricular approach, we suggest some possibilities that teachers should lead during the process in two moments:

*a) analysis of the proposal:*

The structure of the subject's contents based on Figure 1 allows us to observe two important dimensions for a teaching and learning process: on the one hand, the teacher as a mediator of knowledge, and on the other, the student as a potential individual to appropriate real problem situations with private and collective assessment activities that must appreciate his autonomy, his responsibility towards nature and respect for cultural, political, economic and social diversity.

In addition, the theme must consider brazilian legislation, attending ethical and democratic principles necessary for the construction of citizenship and respect for diversity.

The teacher must propose activities that create in the student the autonomous thinking of logical-critical reasoning and the ability to argue against situations in their daily lives, bringing up reflections and considerations about the role of science through processes, practices and procedures of analysis and investigation, aiming to stimulate systemic observation, curiosity, elements of experimentation, interpretation, discussion of results, synthesis of information with records and his communication (HERMES, 2019).

Activities of the theme, in turn, allow to present a didactic bias that helps the teacher to develop dynamics and individual exercises, in pairs or in groups aimed at the interaction between students for social coexistence, the understanding of the difference with their peers, social groups, families and the population, always bringing traffic safety guidelines, and the teacher should lead the process of knowledge mediation in a contextualized, interdisciplinary way to focus on formation for



citizenship.

We also highlight that the teacher must (re)plan their classes until the search for means of learning for the students and, for this action, select the best proposals so they can feel like individuals who build knowledge and are active in society, in order to develop their skills and necessary competences to a practice of scientific learning (CHIQUELLO, 2011).

Such action will align to the CNCB with the Physics curriculum, in attempt to search for the best instruments of pedagogical intervention and knowledge assessment, in which the assessment should not be related simply to measuring the development of knowledge, as proposed by the Group for the Re-design of Physics Teaching (GREF, 1998).

Therefore, the idea of a pedagogical curriculum approach is not to bring ready-made and rigid scripts to the teacher and students, but instead a tool that contributes to a more just and egalitarian society, in conditions of inserting them as citizens who collaborate, participate, and interact with the making of a world with more equity and harmony.

*b) The action in the classroom:*

The teacher, when analyzing the pedagogical curriculum approach, should note that the proposal presents an articulation between theory and practice, the development of a discussion updated and integrated to the context of the student, striving for respect, appreciation of cultural, social, political and economic differences, as well as stimulating him to social coexistence, establishing relationships between the knowledge he already has and the new knowledge to be acquired in science education, in a way to develop the skills and abilities set forth in the CNCB.

It is also noted the well-defined objectives and the necessary learning skills to be developed, which avoids multiple or confusing interpretations to the student and thus ensures didactic coherence with the CNCB to allow the construction of knowledge and the progression of student learning in the classroom and, consequently, excels in facilitating the conceptual, attitudinal, and procedural relationship of those students, assigning them the sociocultural role in the search for knowledge through relationships that they establish with knowledge (CARVALHO and SASSERON, 2018).

In this way, it is possible to insert the student as a creator of scientific

knowledge, explaining that the attitude in the classroom should be modified with different stimuli and resources, aiming at a strategic investigation planning focused on studies, observation and scientific research, giving him the role of opinion maker in the social sphere and investigator of his everyday life, enabling pedagogical relationships in theory and practice and in the interrelationships (RICARDO and FREIRE, 2007; CORDEIRO-RODRIGUES *et al.*, 2020).

Therefore, among the diversified strategies we still suggest adopting didactic procedures to mediate the student's knowledge with studies of his surroundings, searching for scientific information in reliable places, observing and recording information, synthesizing and arguing about knowledge, developing interactive and collaborative work, developing researches, elaborating conceptual maps, performing practical activities, debating, planning, arguing about what was observed, and relating it to other means to better organize his scientific knowledge.

#### **4 Making some considerations**

Discussing and choosing a list of contents to be taught in the classroom still seems trivial to all basic education teachers, even to the most experienced ones who develop their pedagogical planning for many years in the same subject.

As our practice is on teaching, research and extension activities, we realize how recurrent this is in Physics, particularly in Integrated High School, when the teacher is still the central figure of the process and students have little immersion in the area.

Discussing curriculum for Physics teaching goes beyond what we propose in this investigation, which assures us to instigate other teachers and researchers so that our pedagogical actions echo in new horizons of the educational field, not only as theoretical proposals but also as quality and excellence practices of citizenship education, similar to the analysis with CNCB competencies identified in High School by Lopes and Araújo (2020).

In these terms, bringing up the discussion, by articulating contents from Newton's Laws, through our pedagogical experiences, constitutes a subject considered primordial in Integrated High School, and this is the main foundation that theoretically sustains Newtonian Mechanics, since almost the entire content of Physics in the 1st grade of schools can be interpreted by at least one of the three laws that govern movements.

This fact alone shows that this subject is one that must be carefully approached with students, who will often initiate their contact with Physics for the very first time. Our concern is that an unsuccessful approach to Newton's Laws could easily compromise the entire learning process of Mechanics and, consequently, of other Physics areas in later years.

When thinking about all this relevance of the mentioned content, many Physics textbooks still suggest approaches concentrated basically in two points: (i) use of experiments that prove or help to develop this subject knowledge; and (ii) a historical approach to Newton's Laws, usually starting from Aristotle's ideas, going through Descartes, Copernicus, etc., reaching Galileo's experiments and findings, and finally culminating in Isaac Newton's work, often associating this historical introduction to spontaneous conceptions about the motion of bodies.

Having said that, even knowing the relevance and importance of the approaches mentioned in the previous paragraph, the present investigation brings a reflection about the necessity of the of Newton's Laws approach in Integrated High School based on the literature of the last five years, to identify what we have about pedagogical innovations.

Even if modest, these proposals are not yet strongly linked to a curricular discussion with more dynamic ideas, but they sustain a base related to the systematized contents we usually have; pedagogical proposals that diversify learning are also presented, here considered relevant and debatable by us.

In these terms, the research presented here differs by thinking outside our "comfort zone box", for which we propose a pedagogical curricular approach that includes addressing the content of momentum and its conservation before introducing Newton's Laws to the students, something uncommon in Integrated High School, especially when researching the textbooks adopted by schools.

From this situation and questioning, we base our arguments and justifications on the fact that they are little known even by Physics teachers: Isaac Newton, before enunciating the three laws that govern Classical Mechanics in the first (axiomatic) part of his work, "Mathematical Principles of Natural Philosophy", defined the concept of mass — the *vis insita*, that is, the inert nature of matter that is conceived as a force of inactivity.

He also defined the momentum. In other words, the Physics textbooks used in Integrated High School ignore this aspect and suggest the teaching of Newton's Laws partially dissociated, because in these works the chapter(s) dedicated to the momentum appears long after the study of Newton's Laws, which for us can be streamlined by the curriculum approach we present.

We argue that the pedagogical curriculum approach should not be considered as a rigid and finished product, but as a theoretical-practical construct that can be adapted by teachers according to their realities and teaching contexts.

In this research, we defend precisely the need to teach Newton's Laws concomitantly with the concept of momentum and its conservation well consolidated. Another point is that Newton's second Law is stated in terms of momentum, and it is possible to teach these concepts in an integrated way so that the student sees them how these concepts were historically created and related.

Thus, by highlighting this curricular reflection/discussion, we suggest not only a pedagogical curricular approach to facilitate the teacher's didactic action regarding these contents, but also as an alternative to work conceptually the Physics teaching, treated here applying Newton's Laws by their association with the concept of quantity of motion.

Therefore, the subjects approached and the activities proposed are, in their didactic-pedagogical function, diversified and present an opportunity to guide the student to become autonomous in learning, to make conscious decisions, to have freedom to express his opinions and to become responsible for himself, for others and for nature, in order to elaborate arguments and broaden his critical thinking and scientific worldview.

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