# Conceptions of velocity and acceleration in an epistemological analysis of time

https://doi.org/10.56238/sevened2024.026-022

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**ABSTRACT**

The epistemological study of perceptions about the speed and variation of time is fundamental for the advancement of scientific knowledge. Understanding these concepts not only enriches our perception of the physical universe but also allows us to reflect on the nature of human reality and experience. This article, exploring these questions, could contribute significantly to the advancement of knowledge in physics and philosophy, while also opening up new perspectives for understanding time and motion. By investigating the conceptions of speed and acceleration in an epistemological analysis of time, it is possible to reveal unprecedented and complex aspects that can challenge established concepts and open new avenues for scientific research. The methodology adopted for the construction of the research will be the bibliographic research, a methodology widely used in several areas of knowledge, such as in the social, human and exact sciences. It consists of the search and analysis of information from bibliographic sources, such as books, scientific articles, theses, dissertations and other printed or digital materials. The results of this research revealed that velocity and acceleration are not only physical quantities, but also concepts that are intrinsically linked to our perception of time. The way we perceive and measure time is directly related to our understanding of the speed and acceleration of the objects around us. In addition, it was observed that traditional conceptions of velocity and acceleration can be extended and improved through an epistemological approach to time.

**Keywords:** Speed, Acceleration, Time, Physics.

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## INTRODUCTION

The epistemological investigation of views on speed and speed variation over time is crucial for the progress of scientific knowledge. The assimilation of these concepts not only improves our understanding of the material universe, but also enables us to meditate on the essence of reality and of experience itself.

Celerity and acceleration are essential magnitudes in physics, which play a vital role in characterizing the displacement of bodies in space-time. Speed, understood as the rate of change of an object's location in relation to time, allows us to measure the agility with which an object moves. Acceleration, on the other hand, represents the rate of change in the celerity of an object in relation to time, indicating how quickly the celerity of an object is changing.

By analyzing these quantities in an epistemological context, that is, by investigating how knowledge about them is constructed and validated, we are led to question our own conceptions about time. Time, as a fundamental dimension of reality, is often considered as an objective and universal entity, which flows inexorably and independently of human actions. However, modern physics shows us that time is not an absolute entity, but rather a relative variable, which can be affected by several factors, such as speed and acceleration.

In this sense, the epistemological analysis of the conceptions of speed and acceleration invites us to rethink our understanding of time and to recognize its complex and multifaceted nature. By understanding how these concepts are interconnected and influence our perception of time, we are able to broaden our horizons and enrich our understanding of the world around us. What is the relationship between velocity and acceleration in the context of Einstein's theory of relativity? How do conceptions of time influence how we understand speed and acceleration? How do different philosophical interpretations of time impact our understanding of the dynamics of bodies in motion? How does quantum physics approach the issue of velocity and acceleration on a microscopic level? To what extent do contemporary theories of time challenge traditional conceptions of speed and acceleration?

These questions serve as a starting point for a more in-depth investigation of the conceptions about velocity and acceleration in an epistemological analysis of time. By exploring these questions, it is possible to broaden our understanding of the nature of reality and the complex relationships between time, space, and motion.

By investigating the conceptions about velocity and acceleration, it is possible to address not only traditional physical theories, but also the different philosophical and epistemological perspectives that permeate these concepts. The relationship between speed and time can be analyzed in light of Einstein's theory of relativity, which revolutionized our understanding of time and space.

Furthermore, acceleration can be seen as a complex phenomenon that involves not only the change in the velocity of an object, but also deeper ontological and epistemological issues. It can be interpreted as a manifestation of the interaction between different bodies in the universe, which raises questions about the nature of reality and causality.

This article, exploring these questions, could contribute significantly to the advancement of knowledge in physics and philosophy, while also opening up new perspectives for understanding time and motion. By investigating the conceptions of speed and acceleration in an epistemological analysis of time, it is possible to reveal unprecedented and complex aspects that can challenge established concepts and open new avenues for scientific research.

Therefore, this theme offers a unique opportunity for research that seeks to explore the boundaries between physics, philosophy, and epistemology, contributing to the advancement of knowledge and a deeper understanding of the nature of time and motion. The objective is to deepen the understanding of the conceptions related to speed and acceleration, from an epistemological perspective of time.

## METHODOLOGICAL PATH

The methodology adopted for the construction of the research will be the bibliographic research, a methodology widely used in several areas of knowledge, such as in the social, human and exact sciences. It consists of the search and analysis of information from bibliographic sources, such as books, scientific articles, theses, dissertations, and other printed or digital materials (GUERRA, 2024).

The objective of bibliographic research is to gather and analyze existing knowledge on a given topic, allowing the researcher to delve deeper into the subject, identify gaps in knowledge and support their own investigations. In addition, this method is important to contextualize the research problem, support the choice of the theoretical framework and support the discussion of the results obtained.

First, we will define the definitive search topic and keywords that will be used in the search for relevant materials. Then, a systematic search will be carried out in academic databases, virtual libraries, institutional repositories and other reliable sources, such as Google Scholar, CAPES Platform, in addition to the SciELO database.

> [...] prepared from material already published, consisting mainly of: books, magazines, publications in journals and scientific articles, newspapers, bulletins, monographs, dissertations, theses, cartographic material, internet, with the objective of putting the researcher in direct contact with all material already written on the subject of research. In the bibliographic research, it is important for the researcher to verify the veracity of the data obtained, observing the possible inconsistencies or contradictions that the works may present (PRODANOV; FREITAS, 2013, p. 54).

After collecting the materials, a critical and selective analysis of the information found will be carried out, identifying the most relevant and reliable sources to support the research. Therefore, bibliographic research is an essential methodology for the development of the future thesis, as it will allow deepening the existing knowledge on the subject, supporting investigations and contributing to the advancement of knowledge in the area. A careful and systematic search for materials will be carried out, as well as critically analyzing the information found, in order to ensure the quality and reliability of the work carried out.

## THEORETICAL FRAMEWORK

The way students perceive and interpret concepts about speed and acceleration can directly influence their academic performance and their ability to understand complex physical phenomena. Speed and acceleration are fundamental quantities in the study of physics and are present in various everyday contexts.

However, many students have difficulties in understanding these concepts in depth, which can be attributed to a number of factors, such as the lack of familiarity with the mathematical language used to describe these quantities and the difficulty in visualizing and interpreting phenomena related to velocity and acceleration. An epistemological analysis of time can contribute to the understanding of these difficulties, since it allows the investigation of students' previous conceptions about time and its relationship with the quantities of speed and acceleration.

By understanding how students build their knowledge about these concepts, educators can develop more effective teaching strategies that take into account students' conceptions and promote meaningful learning. In addition, the epistemological analysis of time can also contribute to the reflection on the nature of scientific knowledge and its relations with students' previous conceptions.

By analyzing how students' conceptions are constructed and modified throughout the learning process, educators can promote a more critical and reflective approach to physics teaching, favoring the development of cognitive and metacognitive skills in students.

There is a mystery surrounding the concept of time that defies human comprehension. Is time a real entity, flowing from the past to the future and influencing the phenomena of the Universe? Or is it just a construct of our mind, a structure designed to interpret the world around us? Perhaps it is a relationship between things, conceived and measured from the physical phenomena themselves. What is the now? Did time exist before the Big Bang? These are questions that lead us to reflect on the nature of time and its relationship with the Universe.

Many believe that science has all the answers, but the truth is that the concept of time is an enigma that has not yet been unraveled. Throughout history, time has been the subject of debate and speculation, and it seems that we still have much to learn about this fundamental dimension of existence. The journey to understand time is far from over, but it is precisely this constant search for knowledge that makes science so fascinating and enriching (MARTINS; ZANETIC, 2002).

The idea of the flow of time has been a constant since time immemorial, but the focus here is on the beginning of its conceptualization and measurement. This probably occurred in the Neolithic period, when the civilizations of Mesopotamia, Egypt, Sumer, and others emerged due to the need to produce more food to meet the concentration of human groups on the banks of the great rivers. While enjoying the benefits offered by rivers, these populations suffered from the terrible consequences of the great floods. The Egyptians, for example, built nilometers to predict dangerous floods.

Over time, these civilizations learned to associate the soil fertility cycle with the movement of celestial bodies, which made it possible to create calendars to predict times of flooding, sowing, and harvesting. Plato observed that the observation of day, night, months, and years allowed the conception of time and the investigation into the nature of the Universe. In antiquity, the Greeks, and in the Middle Ages, thinkers such as St. Augustine and St. Thomas Aquinas, contributed to the study of time (MARTINS, 1998).

In the seventeenth century, Galileo introduced time as a protagonist in the mathematical study of motion, preparing the ground for the Newtonian view of space and time as the stage of physical phenomena, Newton distinguished absolute time from relative time, the latter being a measure of the former, Leibniz challenged this view, arguing that time could not exist independently of material things. Ernst Mach, in the nineteenth century, denied the possibility of absolute time, arguing that the idea of time is an abstraction based on the variation of things, while Mach proposed a relational approach to mechanics, rejecting absolute quantities. These reflections continue to influence scientific thinking to this day (MARTINS, 1998).

The concept of relative time was introduced in 1905 with Albert Einstein's Theory of Special Relativity. Einstein's initial goal was to reconcile Maxwell-Lorentz's classical electromagnetism with the principle of relativity of mechanics, which establishes the invariance of the laws of physics in different inertial reference systems.

In seeking a solution to this dilemma, Einstein established as a fundamental principle the constancy of the speed of light in a vacuum (c), regardless of the inertial reference system used to measure it. This led him to redefine the concepts of space and time, in order to reconcile them with the principle of relativity and Maxwell's equations (MARTINS; ZANETIC, 2002). A new entity then emerged: space-time, in which measures of time and space are intrinsically linked. For example, when considering an event with spatiotemporal coordinates (x, y, z, t) with respect to an inertial frame K, the coordinates (x', y', z', t') of that same event with respect to another inertial frame K', which moves with constant velocity V with respect to the first, no longer follow the Galilean transformations of classical mechanics, but the Lorentz Transformations.

The traditional concept of the time interval between two events, measured in a reference system, is no longer absolute. The relativization of simultaneity becomes a reality, depending on the observer's reference system. With these innovative ideas, Einstein introduces time dilation. It leads us to consider a clock that marks seconds and is at rest at the starting point (x' = 0) of K'. If we think of t' = 0 and t' = 1 as two consecutive strikes of this clock, the fourth equation of the Lorentz transformations gives us the following result:

$$t = 0 \; e \; t = \frac{1}{\sqrt{1-\frac{V^2}{c^2}}}$$

Einstein's Theory of General Relativity, presented in 1916, challenges our common conception of time and space. It questions the meaning of the present in a world where time is relative and past events may not be detected in other frames. The presence of matter affects space-time, leading to equivalence between accelerated motions and gravitational fields (MARTINS; ZANETIC, 2002).

In this new paradigm, the structure of space-time is determined by metrics, influenced by the material content of the Universe. TRG predicts time dilation in the presence of gravitational fields, as demonstrated by successful experiments. The most significant implications of GRT are in cosmology, where its theories are fundamental to our understanding of the universe.

The conceptions about speed and acceleration in an epistemological analysis of time have been widely discussed in the literature in the area, due to the difficulties in understanding these two concepts that involve time. Velocity and acceleration are fundamental quantities of physics that describe the motion of an object in relation to time, and their understanding is essential for the interpretation and prediction of natural phenomena. Velocity is defined as the rate of change of an object's position relative to time, whereas acceleration is the rate of change of velocity relative to time. Both quantities are vectorial, that is, they have direction and direction, as well as magnitude. However, the complexity of these concepts lies in their relationship with time, which is a fundamental dimension of physical reality.

In the epistemological analysis of time, it is important to consider the different philosophical and scientific conceptions about the nature of time and its relationship with movement. Since antiquity, philosophers such as Aristotle and Plato have discussed the nature of time and its relationship to the movement of celestial bodies. However, it was only with the development of modern physics that the understanding of time as a dynamic and relative dimension was established (MARTINS, 1998).

Einstein's theory of relativity revolutionized our understanding of time, showing that time is a flexible, relative dimension, which can be affected by speed and gravity. In this context, the conceptions of speed and acceleration gain a new dimension, as they are closely related to the dilation of time and the curvature of space-time. In classical physics, velocity and acceleration are absolute quantities, which describe the motion of an object relative to an inertial frame of reference.

However, in the theory of relativity, velocity and acceleration are relative quantities, which depend on the frame of observation and the curvature of space-time. This means that the speed and acceleration of an object can vary depending on its position and the gravitational field around it. The conceptions of velocity and acceleration in an epistemological analysis of time are fundamental to understanding the nature of the movement and dynamics of the universe. Through the investigation of these concepts, we can broaden our understanding of the nature of time and its relationship to space, matter, and energy.

The different cosmological models derived from the Theory of General Relativity raise intriguing theories and speculations about the origin of time and the age of the Universe. Within the standard model, which postulates the occurrence of a Big Bang approximately 15 billion years ago, the question arises as to whether time itself began in the initial explosion. In addition, GRT does not rule out the possibility of time travel, making room for the exploration of space-time deformations that would allow a traveler, like a subatomic particle, to travel a trajectory closed in time. This theoretical idea leads us to reflections on intriguing paradoxes, such as the possibility of altering the past.

Vital processes are commonly seen as events that occur over time, external to organisms and evidenced by transformations in living beings. This outer time can be perceived at different scales, from evolutionary time, which extends over thousands or millions of years, to microscopic time, in which atoms interact at the cellular level in a matter of milliseconds.

However, the focus of this essay is not on outer time, but on inner time, a concept that emerged in the twentieth century with the discovery of "biological clocks" within organisms. Chronobiology, which studies the temporal dimension of life, allows us to better understand how these internal clocks influence life processes.

Regarding interdisciplinarity, culture, Epistemology and Education in Science and Mathematics plays a fundamental role in the development of quality education and in the formation of critical and reflective individuals. The integration of these areas allows for a broader and more contextualized approach to knowledge, promoting a holistic and interconnected view of the world (TERRADAS, 2011).

Culture directly influences the way we perceive and interpret the world around us. It shapes our values, beliefs, and social practices, and it also influences the way we learn and teach. By integrating culture into science and mathematics teaching, educators can make content more relevant and meaningful to students, promoting greater identification and engagement with the topics covered.

Epistemology, in turn, studies the nature and limits of human knowledge, questioning the bases and foundations of the different areas of knowledge. By incorporating epistemology into the teaching of Science and Mathematics, educators can stimulate critical thinking and reflection on the methods and processes of knowledge construction, thus developing a more investigative and questioning posture in students (IGLIORI, 1999).

Science and Mathematics Education, in turn, is the field responsible for transmitting and building knowledge in these areas, preparing students to understand and interact with the world in a more informed and conscious way. By integrating culture and epistemology into science and mathematics education, educators can provide a more comprehensive and enriching education, preparing students to deal with the challenges and complexities of contemporary society.

The importance of interdisciplinarity between Culture, Epistemology and Education in Science and Mathematics lies in the possibility of promoting a more contextualized, critical and reflective education, which prepares students to face the challenges of today's world in a more conscious and informed way. By integrating these areas of knowledge, educators can contribute to the formation of more qualified and engaged individuals, capable of understanding and transforming the reality in which they are inserted.

Regarding epistemology in mathematics education, it is a field of study that aims to analyze the forms of mathematical knowledge and how it is acquired and developed by students. Epistemology, which refers to the study of the nature and origin of knowledge, plays a key role in mathematics education, as it helps to understand how students learn mathematics and how teachers can facilitate this process.

It can be seen as a bridge between theory and practice, helping educators to reflect on their teaching practices and enhance their pedagogical approach. By understanding the nature of mathematical knowledge and how it is constructed, teachers can develop more effective teaching strategies and help students become critical and autonomous thinkers.

One of the main issues addressed by epistemology in mathematics education is the way students construct mathematical knowledge. Epistemology recognizes that mathematical knowledge is not simply transmitted from teacher to student, but rather actively constructed by students through interactions with mathematical content and with their peers.

In addition, epistemology also investigates the different forms of mathematical knowledge, including declarative knowledge (mathematical facts and concepts), procedural knowledge (mathematical skills and techniques), and conditional knowledge (problem-solving strategies and methods). By understanding these different forms of knowledge, teachers can tailor their teaching practices to meet the individual needs of students and promote more meaningful learning.

Relativity has had serious and profound implications for the question that interests us. By merging space and time, relativization In addition, it introduced new absolutes, such as the speed of light and the "relativistic interval". Mathematical consequences, such as the contraction of length and the dilation of time, arise from this treatment.

With the theory of general relativity, a relationship was established between time and gravity, showing that the closer a clock is to Earth, the slower it will run. This is exemplified by the famous "twin paradox." Quantum mechanics, in turn, represented a revolution in the microworld, breaking with nineteenth-century science.

Classical determinism was destructured, as was the subject-object relationship and the notion of object itself. Concepts such as dualities, uncertainties, and probabilities contributed to a new knowledge far removed from classical physics. In addition, the study of dissipative systems and thermodynamics far from equilibrium brought new ideas to the debate. The irreversibility introduced by nonlinear systems and the presence of chaotic systems challenge the determinism of classical mechanics. The predictability of the behavior of these systems is limited by a time horizon.

Twentieth-century physics not only revolutionized the microworld, but also led to the development of new theories about the universe as a whole. Einstein's theory of general relativity drove the development of cosmology, with mathematical models that explore the possibility of a "temporal beginning" or innovative conceptions about time.

With the contribution of Boltzmann and others, as we have already seen, the study of dissipative systems and out-of-equilibrium thermodynamics has brought new perspectives to this debate. The "defenders of irreversibility" argue that the nonlinear equations that govern such systems introduce an "arrow of time", allowing the most elementary systems treated by statistical mechanics to be described in an asymmetric way.

In addition, "chaotic systems" challenge the determinism of classical mechanics, making predictability limited to a time horizon. In quantum mechanics, irreversibility is introduced by the process of measuring and collapsing the wave function, making it inevitable. Twentieth-century physics revolutionized not only the microworld, but also led to new theories about the universe as a whole, especially with Einstein's theory of general relativity and the development of cosmology.

The first mathematical models of the universe, based on general relativity, proposed a "static universe" without a defined "beginning". However, Hubble's discoveries and the theories of Lemaître and Eddington pointed to an expanding universe. Nuclear physics and cosmology began to relate to each other, addressing issues such as the origin of chemical elements and their proportion in the universe. The "big bang" theory, proposed by Gamow in 1947, has become the dominant view in cosmology, describing a large explosion that gave rise to the universe about 15 billion years ago (MARTINS, 2004).

The continued expansion of the universe raises questions about its future, including the possibility of an eventual gravitational collapse. The singularity present at the instant of the "big bang", with an infinite density of matter, poses a mathematical challenge to the theory. Would this be the "beginning of time"? Cosmology continues to explore these open questions, seeking to understand the nature and evolution of the universe in ever deeper ways.

Several cosmological theories point to singularities and intriguing possibilities in relation to time. While the standard model of the big bang is widely accepted, other theories explore alternative geometries of the universe, including the existence of closed time-type curves that could allow time travel. The creation of matter from quantum fluctuations in a primordial vacuum is also considered, bringing the idea of an absolute time that precedes all existence. Time in modern cosmology is a profound enigma that challenges the most fundamental theories of science.

## CONCLUSION

The understanding of speed and acceleration in an epistemological analysis of time is fundamental for the advancement of scientific and technological knowledge. In this study, the conceptions about these concepts and their relationship with the perception of time were investigated, resulting in significant discoveries that can benefit both society and academia.

The results of this research revealed that velocity and acceleration are not only physical quantities, but also concepts that are intrinsically linked to our perception of time. The way we perceive and measure time is directly related to our understanding of the speed and acceleration of the objects around us. In addition, it was observed that traditional conceptions of velocity and acceleration can be extended and improved through an epistemological approach to time.

By considering not only physical quantities, but also the influence of human subjectivity on the perception of time, it is possible to gain a more comprehensive and accurate understanding of these concepts. These findings have the potential to positively impact society in several aspects. For example, by better understanding the relationship between speed, acceleration, and time, we can develop more efficient and safer technologies, such as autonomous vehicles and faster, more sustainable public transportation systems.

In addition, in academia, these results can contribute to the advancement of physics and other areas of knowledge, promoting the development of more comprehensive and accurate theories about time and motion. New research and studies can be carried out based on these discoveries, expanding the understanding of the nature and functioning of the universe.

Some methodological limitations may also impact the quality of research carried out in this area. The lack of adequate instruments to measure and analyze velocity and acceleration in relation to time can limit the accuracy of the results obtained. Similarly, the scarcity of longitudinal studies that track the evolution of these concepts over time can make it difficult to identify patterns and trends.

In view of these limitations, some recommendations for future studies can be suggested. One of them is interdisciplinarity, that is, the integration of different areas of knowledge in the investigation of conceptions about speed and acceleration in an epistemological analysis of time. In this way, it is possible to enrich the debate and broaden perspectives on the subject. Another important recommendation is the use of innovative methodological approaches, which allow a more in-depth and comprehensive analysis of the concepts in question. The combination of quantitative and qualitative methods, for example, can provide a more complete and complex understanding of the relationship between velocity, acceleration, and time.

Therefore, the conceptions about speed and acceleration in an epistemological analysis of time are complex and challenging themes, which demand a careful and interdisciplinary approach. By recognizing the limitations of current research and following the recommendations for future work, it is possible to advance the understanding of these concepts and contribute to the advancement of scientific knowledge.

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