

# Trains, clocks, rulers, twins: Images in relativity teaching



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## Abstract

In this paper, we aimed to understand the interpretations of Physics students in relation to the images' functioning in relativity teaching. We sought to find answers to the questions: a) How do Physics undergraduate students position themselves in relation to images, chosen by them, for relativity teaching or, more specifically, which aspects they take into account when selecting an image addressed to High School? b) How do they establish the meanings they attach to these images? For that, we took, as space, actions carried out in a curriculum discipline of Physics Education Course at one of three public universities from São Paulo, attended by 18 students. In one of the activities from the discipline, the teacher asked for students choosing at least three images they would use to explain relativity issues/concepts. The question asked was: If you were use an image to teach a relativity subject/concept, which image would you choose? Justify your choice and state the criteria used for choosing. In this study, the analysis focuses on the answers provided by students for the activity requested. We used Discourse Analysis, initiated by M. Pêcheux to examine the obtained data. The speeches' analysis allows inferring that: a) there is a clear relationship, in students' speeches, regarding images choice and the subject to be taught; b) probably the media, either printed or television, has influenced on images choice; c) in students' speeches, we realized the importance attributed to elements from their discursive memories, mainly, when they considered their previous histories to chose the images; d) the speeches seem to indicate at least two types of images' functioning. In the first, the images serve as motivators for the learning; and; in the second, as auxiliary in the understanding of the taught subject.

**Keywords:** Images, relativity, discursive memory.

## Resumen

En este trabajo, nuestro objetivo es entender la interpretación de los estudiantes de física sobre el funcionamiento de las imágenes en la enseñanza de la relatividad. Nosotros intentamos encontrar la respuestas a las preguntas: a) ¿Cómo los estudiantes de pregrado en física se posicionan en relación con las imágenes que han elegido para la enseñanza de la relatividad, o más específicamente cuáles son los aspectos que tener en cuenta a la hora de la selección de una imagen destinada a la enseñanza?; b) ¿Cómo ellos establecen los significados que atribuyen a estas imágenes? Por lo tanto, nosotros usamos como espacio de investigación las medidas adoptadas en una disciplina de la Física en una de las tres universidades públicas de São Paulo, al que asistieron 18 estudiantes. En una de las actividades de la disciplina, el maestro preguntó a los estudiantes a elegir tres imágenes que se utilizan para explicar los problemas y conceptos de la relatividad. La pregunta fue: Si usted fuera a utilizar una imagen para enseñar un tema o concepto de la relatividad, que foto te quedarías? Justificar su elección y establecer los criterios utilizados para la selección. En este estudio, el foco de análisis se centra en las respuestas que los estudiantes referente a la actividad solicitada. Se utilizó el análisis del discurso, iniciado por el Sr. M. Pêcheux, para examinar los datos obtenidos. El análisis de inferir que: a) existe una clara relación en el discurso de los estudiantes en cuanto a la elección de las imágenes por el contenido que se enseña, b), probablemente los medios de comunicación, ya sea impreso o en televisión, tiene influencia en las imágenes seleccionadas, c) en los discursos de los estudiantes se dan cuenta de la importancia dada a los elementos de su memoria discursiva, especialmente cuando se considera su historia anterior para seleccionar las imágenes, d) los discursos parecen indicar al menos dos tipos de carreras para las imágenes. Al principio, las imágenes sirven como motivadores para el aprendizaje y el segundo como ayudas a la comprensión de los contenidos.

**Palabras clave:** Imágenes, relatividad, memoria discursiva.

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## I. INTRODUCTION

In Lewis Carroll work, entitled *Alice in Wonderland* [1], the main character was beginning to get tired of being sitting beside her sister and has nothing to do. Once or other, she looked at the book her sister was reading, but in the book there were not any images or dialogues and Alice asked herself: What is the purpose of a book without images or dialogues?

Manguel [2] mentions that the images, as well the words, are the material from which we are made. They are as in our thoughts as in the majority of the media around us daily. In especial, the images are important resources for diffusing scientific ideas, in the concept formation and in the visualization and intelligibility of several scientific texts. Hence, dealing with them, knowing how to comprehend and interpret them is part of learning.

If we think specifically in teaching a specified scientific subject, for instance, in Physics case, the relativity theory, how we could think on images as knowledge mediators?

We took as premise that images are texts constitutive resources, considering that reading the same and, consequently, the meanings production by whom read them are associated to the images functioning. Although, the reading is considered a meaning construction process, in which author's intentionality, materiality of the text and the reframing possibilities from the reader play [3].

## II. PURPOSE, GUIDING QUESTIONS AND STUDY JUSTIFICATION

We aimed to comprehend the Physics students' interpretations regarding to images functioning in narrow relativity teaching in high school. We sought answering the following questions: a) How do Physics undergraduate students position themselves in relation to images, chosen by them, for relativity teaching or, more specifically, which aspects they take into account when selecting an image addressed to High School? b) How do they establish the meanings they attach to these images?

The study justifies itself since that as didactic texts as text designed for diffusing relativity theory present images in their explanations. In these productions, we perceived images. Einstein [4] uses just an image, which for him represents a train, illustrated bellow.

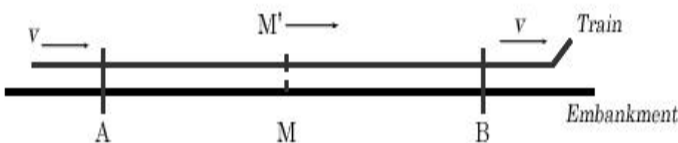


FIGURE 1. Picture used by Albert Einstein in his work: "A teoria da relatividade especial e geral" [4].

To comprehend these images functioning in the understanding of relativity theory, the relations between them and the meanings attributed by the ones who read them, and how they participate in the Physics students understandings, when they read texts on relativity, becomes an important investigation theme.

The choice for relativity can be justified not only due to its relevance inside Modern and Contemporary Physics, but also due to the fact that the German Physic Albert Einstein (1879-1955) is well-known not just as a great scientist and a figure in our culture, but also mainly because he got worried, throughout his life, upon diffusing his theories' subjects, as to a specialized as to lay public.

## III. STUDY DEVELOPMENT AND THEORETICAL FRAMEWORK

For developing this study, we took as space the actions carried out in the discipline "knowledge on School Physics II", attended by 18 students. This discipline is part of the curriculum for Teacher Course in Physics, diurnal, in one of the three public universities from São Paulo.

In one of the activities carried out during the discipline, we asked for students answering some questions, which involved, among other aspects, the importance they attributed to the images in the specific case of teaching Physics subjects and their interpretations regarding to images functioning in teaching and learning process, particularly, in relativity theory teaching. We asked also for students choosing at least three images that they would use to explain subjects/concepts upon relativity. The question elaborated was: If you were use an image to teach a relativity subject/concept, which image would you choose? Justify your choice and state the criteria used for the choice.

The students had one-week-time for looking for the images and bringing them with the justifications for the choice. In the end, we asked for analyze and interpret a set of images that commonly is employed in textual explanations upon relativity theory. In the present study, the analysis focused on the answers for the question above presented.

Since that we tried comprehending Physics undergraduate interpretations, we used Discourse Analysis (AD), begun by M. Pêcheux. In this approach, the discourse is the meanings effect between announcers. Still, it is considered the language non-transparence and ideology, historic and cultural influences that are behind the construction of all discourse. Orlandi [5] highlights some aspects which need to be taken into account in AD: the subject; the language and its historical process; the analysis devices; the production conditions. The use of this theoretical framework is justified because it roams the speech with the intention of seeking the information meaning and what led including one or other information into the discourse. Therefore, we looked at the discourse, which has always plenty of meaning, of subjectivity, of arguments, of meanings effects exposed by its interlocutors.

#### IV. THE SPEECHES MADE AND THE MEANINGS ATTRIBUTED

In order to exemplify, we focused the analysis on the use of words and expressions in the speeches made, which reveals possible meanings attributed by the individuals.

We are going to present some cases that seem to be more meaningful and point a possible chosen images functioning.

An image that was recurring in students' choice was the one from Einstein, as we realized in the speeches 1, 2 and 3.

"My first contact to relativity theory was when I was attending the second year of high school, and I watched a movie about the twins' paradox and the energy equation. Today, seeking in my thoughts the three images, for me, I believe that were those which got recorded since that time. The first image I chose, explains itself. The energy equation and Einstein photo with his tongue outside. I think that, it is the most well-known equation in the world and one of the photos more diffused of our epoch" (speech 1).

"As soon we think on relativity, the name Albert Einstein comes together almost as a synonymy. And, talking about Einstein, soon his image with the tongue outside is associated. When, we search on Einstein through the internet, 50% from the images found are similar to that. It would be interesting to show to students that Albert Einstein was not just a crazy stereotype. He had a social life behind it. A family, a wife, the children" (speech 2).

"This image is important to talk about relativity, for probably without him, the relativity would take more time to be discovered. Knowing Einstein and few about his history is good for a cultural enrichment when we are studying relativity, for knowing just how it works without knowing how it was originated is something poor regarding to the knowledge" (speech 3).



FIGURE 2. Source: Halliday and Resnick [6].

The chosen image by the student (speech 1) adds Einstein's face and the equation of mass-energy relation. Viviane has bachelor degree in Physics and she is attending the Teacher Course. In her speech, it is evidenced the search for images that were representative in her first contact to relativity. The

*Trains, clocks, rulers, twins: Images in relativity teaching* student seeks in her living memories justifications for her choices; images that were present in a movie watched when she was in high school.

For the student, the fact of Einstein photo and equation being the most diffused by the media seems to be criteria for her choice. Maybe for her, this image and the equation cannot be left without be showed by the teacher in relativity teaching. It seems to contribute to the old scientist conception, presents into the imaginary of a great part of population, that is, a being endowed with genius, crazy with hairs lifted up and with several calculations to be solved.

In the second speech, the student argues that Einstein figure and his image with the tongue outside are strongly rooted in his cognitive structure and that they are immediately accessed when the subject is relativity. The student also exposes that, searching on the internet, the result was half of the available images found was similar to the ones he chose. For him, the image must be demystified.

In turn, the third speech, the student uses an Einstein photo in the patents office in Berna, reproduced into the forth volume from the collection *Fundamento de Física*, of Halliday and Resnick. Probably, the student choice is supported by her formal source of information upon relativity theory at the university, it means, by the textbook used by her teachers in basic disciplines of undergraduate course, in which obtained formal information on relativity. Seemingly, the search for image made the student appeals to her memory, positioning herself in favor of a teaching including the scientist history.

The second image which appeared in students' choices was the isosceles triangle, as perceived in speeches 4 and 5.

"This image also from Halliday book, would be an illustration similar to the first two from the previous work. I think this image is important, for with it we get to show the relation time dilatation, subject very important inside relativity" (speech 4).

"Pictures, like the two clocks that measure time while there is a light ray inside the train, are extremely useful in the introduction, in the demonstration of formulas and discussions on Special Relativity Theory" (speech 5).

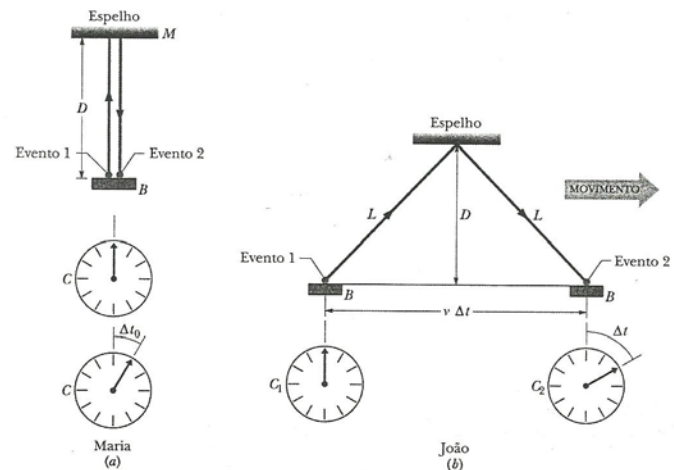


FIGURE 3. Source: Halliday and Resnick [6].

Similarly to the speech 3, the student of speech 4 uses the one that maybe would be his reference to obtain formal information upon relativity theory, it means, the textbook, employed by his teacher in the undergraduate course (Halliday), from which he had the first contact to this theory.

It is noteworthy that the student makes reference to, in his speech, two images worked in a previous activity in the discipline.

The images which he refers are present in a book for science diffusion written by Landau and Rumer [7] and entitled "O que é a Teoria da Relatividade". The images mentioned are presented bellow.

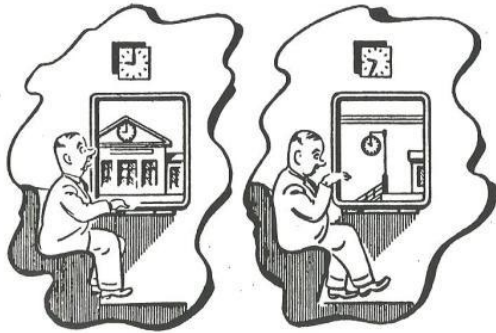


FIGURE 4. Picture mentioned by the student of speech 4. Source: Landau and Rumer [7].

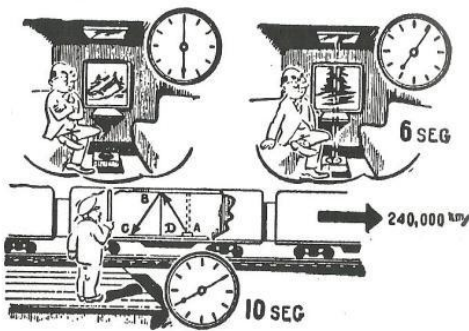


FIGURE 5. Picture mentioned by the student of speech 4. Source: Landau and Rumer [7].

The organization of the fifth speech and use of the expression "figures like" point out certain preference for determined images, becoming evident an association between the image and a subject comprehension. The speech 5 can be read, still, in the following way: "the absence of images as the two clocks that measure time while there is a light ray inside the train, prejudices the introduction, the demonstration of formulas and discussions on Special Relativity Theory.". This reading of the non-said or transposition of the "already-said" indicates, under a silencing way, in that it is not present in speech body, to

produce meanings in other direction, which is the gap/deficiency of explanations and mathematical demonstrations when it is not used certain images.

Other set of images chosen by students regards to the twins' paradox. The image chosen to explain this subject by one of the students is presented at the Fig. 6 and his speech is presented into the sequence.

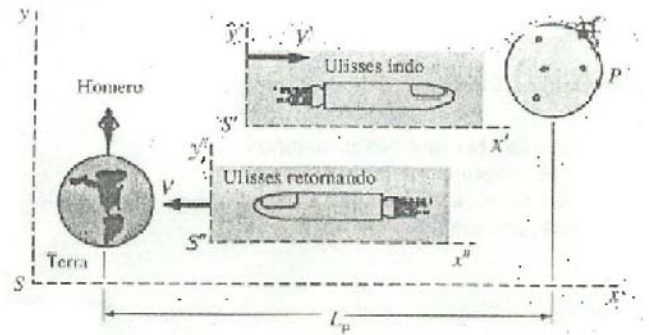


FIGURE 6. Image mentioned by the student of the speech 6. Source: Tipler [8].

"This image can be very useful to explain for students the twins' paradox (despite that in the image Homero and Ulisses were not twins), for we can make an interesting question to students: If Homero stays on Earth and Ulisses travels in a spacecraft with a speed near to the light speed, after some years in relation to ourselves, Ulisses comes back, they will have the same age? Likely, the majority of students would answers that the time would pass equally for both, however, it is not true. As Ulisses would be traveling near to light speed, the time for him, would pass more slowly, so, certainty, if before traveling, Ulisses and Homero had the same age, after the travel, the time for Ulisses passed more slowly in relation to Homero. More important than we get transmitting formulas to the students, the images can be very helpful and, in several cases, clearer than the formulas" (speech 6).

In the speech above, the female student does not make explicit reference to the justifications for her choices. In her speech, she just tries to explain the paradox and mentions how she would act in a classroom context. At the end, she talks about the images importance in comparison to mathematical expressions. Maybe, the fact of the student be inserted in Physics research had made she tried to explain, to the reader of her production, the referred paradox, showing that she has great conceptual knowledge on the subject in question. An indicative for it is the fact that she has chosen an image from a book used in undergraduate course.

"The third image is the one of twins' paradox (in my image are female twins, Ana and Jane). I believe that my teacher from high school made me feel curious and my colleagues too with the idea of getting old in different times. He got all class attention, saying that we could

understand this example through the famous relativity theory. The activity (movie) was great, and I really understood what was being said, despite I did not know the consequences of the theory. I believe that most of the students have curiosity on relativity theory and movies, like *Mechanic Universe*, can help us to introduce the concept owing to their form are nearer of their realities (video) and with a comprehensible language for high school” (speech 7).

The speech 7 seems to evidence, when the student pronounces “in my image”, that she makes use of mental images, and from them, she “goes” looking for a fixed visual image which represents her use intentions in paper and in plan. Yet, the student does not realize that the paradox is already a theory consequence.

The student mentions a life experience she had, of watching the series “The Mechanic universe in its formation in school”. There are evidences in her speech that the fact of the teacher had got everybody’s attention in class seems to be an indicative of dealing with the paradox in class and that this fact can, maybe, be repeated again in her class when she be teacher. Maybe, the student is worried just on how to obtain her students’ attention. On the other hand, it gets clear her worrying of using an accessible language to deal with relativity.

The *Mechanical Universe* is a series, with 52 episodes, produced in 1985 by Caltech (California Technology Institute) and by *INTELECOM Intelligent Telecommunications*, which were exhibited on American television in 1985 and 1986. In this series, it is used historical dramatization and several animations. It is a fascinating travel throughout all the Physics Universe, its history, characters and concepts, since classical mechanic until the quantum, addressed to public in general, but in a depth way enough to catch the most curious’ attention.

In the speeches made, it was possible to identify some justifications presented by the students for using images when teaching relativity. These speeches are reproduced in the sequence bellow.

“Relativity teaching also demands the use of images, since that day-by-day, we do not see concepts as time dilatation, time contraction, time-space curvature, mass-energy equivalence, etc, playing their effects inside this abstract theory. However, it is behind the operation of several current technologies (GPS, control of air navigation, triangulation of radio signals, mobile phone, etc) and, thus, the images used in its teaching can play a decisive role in the comprehension of these concepts for all of the theory” (speech 8).

“I think that images can be used in teaching of any Physics subject, for it makes students visualize the problem (or the explanation) in a better way. The relativity is better taught if it is done together to illustrative draws, actually, without them, it is impossible to understand what the theory means” (speech 9).

The first aspect to be detached in the last two speeches, reproduced above, is that the terms “abstract theory”, “it is impossible to understand what the theory means”, appears

*Trains, clocks, rulers, twins: Images in relativity teaching* in their different combinations, with other constitutive elements from the speeches, producing a meaning effect that reveals a discursive formation, in which relativity theory is taken as of complex understanding, as we realized in the fragments above.

## V. CONCLUSIONS

The speeches made by students seem to indicate not properly choices of determined image that can be used, but subjects and/or concepts that cannot be left without being taught when the teacher deals with relativity in high school, among them Albert Einstein’s photo, Lorentz equation, time dilatation and the discussion on the twins’ paradox.

It seems that, independent from images to be used, it is essential to present an image that shows the theory constructor, even as a way of discussing the historic context of the theory creation. Other important image to be used, according to some students’ conception, is that which presents isosceles triangle in order to explain time dilatation, since that it would help for understanding this subject.

Likely the printed, television or virtual media has influenced on the images choices by the students, what can be noticed through explicit references to this media. In the speeches made, we realized the relevance attributed by the students to elements of their discursive memories, mainly when they consider their previous histories to pick up the images.

The speeches here reproduced seem to point out at least two types of images functioning. In the first, they work as motivators for learning, catching learners’ attention, activating their curiosity and causing impact as, for instance, Einstein image with the hairs lifted up and tongue outside.

In the second, they work as producers of better visualization of the problems emerged from the theory and as agents in the verbal explanations. It can be noticed by the announcers’ condition, who are Physics undergraduate students, who probably will find difficult in comprehending the relativity theory, when studying it in their initial education’s disciplines. Furthermore, the images would work as auxiliaries in the understanding of the subject taught as, for example, the images with trains and with the isosceles triangle to explain the time dilatation.

We emphasize that speeches constitution and meanings produced, do not occur in a static way neither in an automatic one. It is necessary to analyze them from their functioning. In the discursive formations, the use of words and expressions such as “decisive role in the comprehension”, “it makes the students visualize better”, “it is better taught if it is done together”, “without them it is impossible to understand”, “they are extremely useful” seem to indicate possible meanings attributed to the images, meanings which would be in favor of images maintenance in Special Relativity Theory teaching.

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