Using interactive images in physics teaching

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Abstract. Studying images in physics textbooks is important because illustrations are considered relevant to understand physics contents. In fact, images have a fundamental role in textbooks, and facilitate students to enhance physics theory visualization. Silva & Martins (2008) assume that images carry information that can be classified as having a motivating, informative, explanatory or redundant function. We found 223 images in the kinematics units’ analysis of three collections recommended by the last edition of the Brazilian Textbook Program (PNLD 2018). The images were classified according to their function, observing, in percentages, that 52% of images have an informative function, 40% an explanatory function, while the redundant and motivating functions total less than 9%. Moving interactive images have been created from informative function figures using the Illustrator software. This program allows us to create an illusion of movement in the image when moving a page with vertical lines, facilitating the student’s visualization and understanding. These images were presented to the students through a questionnaire. We verified a better performance in their answers with the interactive images, that allows us to infer that moving images can facilitate students’ learning.

1. Introduction
Images constitute an important tool for teaching and learning physics since they allow a clearer vision of abstract subjects. In this perspective, the present research deals with illustrations in textbooks, in order to help students to understand physics concepts. In order to aid the students' understanding, we focus on the use of interactive illustrations through moving images similar to the static ones available in textbooks. The interactive images were produced with the CC 2017 Illustrator software, and the movement can be observed by sliding slowly a transparent sheet with several vertical lines over the images produced by the software as shown below.

![Figure 1: Example of an interactive image produced with the CC 2017](image)
In general, the Brazilian public high schools present a precarious infrastructure with insufficient basic resources. Based on this, our purpose is to help physics teachers who don’t have any didactic science laboratory available. In fact, the absence of laboratories reduces teaching possibilities in class that include demonstrations or experiments that can improve the learning of physics concepts.

We offer an alternative methodology to sophisticated laboratories to be used with the physics textbook, which includes interactive illustrations. The idea is to enable students to perceive a sequence of movements and allow them to better understand and visualize physics concepts.

In fact, a more interactive configuration in the textbooks can aid students to learn easily, and digital technologies can provide visual representations beyond instant access to information. In this perspective, we suggest the use of moving images equivalent to the textbook static ones to complement and diversify teachers’ praxis with the intend to make textbooks more visual and help students’ learning.

2. Conceptual framework
The textbooks use images to illustrate and assist student learning. Ge et al. (2018) reviewed the major cognitive theories and empirical evidence related to the influence of image designs on science learning. It is assured that the use of images has shown much promise, but without proper design and consideration for learners, images may not function effectively or, at worst, may actually impede learning or lead to misconceptions.

According to Silva (2006), image comprehension is not immediate, and to guarantee image understanding in the pedagogical context, teachers are supposed to help students perceive its constructive elements.

On one hand, Perdigão-Nass and Ipolito (2009), value visual representations as an important criterion in textbook selections, demonstrating the relevance of investigating images when conducting textbook researchers. On the other hand, Gibin; Kiill and Ferreira (2009), consider images little explored and they noticed that usually students present different understandings of the same illustration.

Zimmermann and Evangelista (2004) assure that students have difficulty in interpreting real or schematic images, which makes it necessary for teachers to mediate their perception of their constituent elements. Students tend to describe images in a real way without observing other details, which can lead them to an incomplete and sometimes erroneous interpretation.

To sum up, students need guidance in understanding images in their scientific sense. In fact, we consider that the more complex the picture, the greater the students need for teacher assistance to interpret and understand it. Darroz, Rosa e Giaretta (2017) used several methods for image classification in physics textbooks, among which we highlight: its functionality, as it is done in the present research, its iconicity, as it were done by Silva and Martins (2008), and Rego and Gouvea (2013), and its integration (text-image), as it was done by Peterson (2016).

For Rego (2011), the textbook images present peculiarities of scientific rigor that differ from students’ reality. He considers it necessary to replace images with a high degree of abstraction by those that represent daily life. According to the author:

We could imagine a cultural context in which people did not know what is a handkerchief, that is, they saw this piece of cloth and did not recognize its function; in this case they could treat it like anything else, with a very different utility from what we are accustomed to: that piece of cloth would no longer be a handkerchief, that is, it would have a different epistemological objectivity for these people. (REGO, 2011, p. 5).

So, images help the students if they illustrate situations of their daily life with suitable scientific rigor. According to Frederico and Gianotto (2018), images can play an important role in teaching and learning due to their representational properties. In fact, photographs, videos, drawings, graphics, among others, are elements that can be associated with physical phenomena. The word-image association seems to be able to activate specific mechanisms linked to our memory, which facilitates the understanding of concepts or themes. Muller (2019) explores with easy-to-do activities on a Photocopier that permit to associate interactive images to explain Physics phenomena, as harmonic waveform images produced by a vibrating rubber band.
Silva et al. (2006) emphasize that image reading is part of a person’s broad historical background as part of an image network that constitutes one’s reality to face the world. The greater the number of images people have experienced, the better their ability to interpret them. In a conventional classroom, each student comes from a different social-historical background, which leads to different image interpretation degrees. For the authors:

In an age of mass communication, it would not be an exaggeration to say that we know the world more by images. This sense of knowledge is only possible if we "believe" in images, that is, if we assume unconsciously, that what we see through them is real. (SILVA et al. 2006, p. 82).

Martins (2010) considers images as pieces of information that contain instant messages while written information needs to be decoded. In this sense, as images do not need to be decoded, they have in certain situations greater communicative relevance than the written explanations. In this sense, physics teaching must mix real-world experience with scientific knowledge to contextualize the contents. In fact, students construct meanings and understandings in the classroom, and use their daily experiences. Therefore, the use of images establishes a link between the two types of knowledge, and the relationship between the image and the presented object must be considered. To the author:

Different images can represent an object, a situation, a phenomenon in different ways. However, this differentiation only becomes more explicit when comparing different images of the same object. When this is the case, some forms of representation are closer to the perceptual ones, that is, to what is effectively perceived by our senses, as the photographic images. Other forms of representation are constructed, using symbols that imply a certain distance from the represented object. Knowing the differences among representative images of the same object, it is possible to construct an iconicity scale, in which the more iconic images are more distant than the represented object and the less iconic images are closer to the represented object (MARTINS, 2010, p.19).

In this perspective, interactive images can be used to establish a relationship between the student's specific cognitive structure and the scientific knowledge presented by teachers in the classroom. For Martins (2010, p.15):

When the student has not had the opportunity to observe a physical phenomenon, the theory can be perceived as a set of abstract rules, devoid of meaning. This happens because the knowledge presented in classroom may be disconnected to the observed phenomena in everyday life, thus not permitting specific subsumption in their cognitive structure.

Silva and Martins (2008) consider that the image itself has no meaning, acquiring sense only when someone questions what is in it. An image consolidates a set of information and each one has a didactic function, which can be classified as motivating, informative, explanatory, and redundant, as the following described.

Motivating function – In this didactic function, the image is used just to hold students’ attention, making its meaning clear by itself. In fact, no explanatory text is necessary to understand it;

Information function - In this didactic function the image takes the foreground of the didactic discourse which is used to explain the iconic message;

Explanatory function - In this function, the image incorporates directional codes that aim to graphically explain a process which is a relation or a temporal sequence;

Redundant function - In this function, the image transmits information, which is clearly expressed by written discourse already.

We analysed these image functions of Physics textbooks recommended by Brazilian Textbook Program (PNLD). In addition, using the Illustrator Software we created interactive images similar to the textbook ones with the intend to allow students better to understand the physical phenomena.

3. Development

To carry out the present work, we choose the kinematics units from three physics textbook collections approved by the last edition of the Brazilian Textbook Program (PNLD 2018). We selected and analysed the two most and the least chosen collections (see Table 1).
Table 1 Selected physics textbook collections

| Collection | Title                  | Authors            | Publisher edition | Selection criteria   |
|------------|------------------------|--------------------|-------------------|----------------------|
| A          | Física                 | Bonjorno et al.    | FDT 3rd edition   | 1st most chosen      |
|            |                        |                    | 2016              | collection           |
| B          | Ser protagonista       | Fukui et al.       | SM 3rd edition    | 2nd most chosen      |
|            | Física                 |                    | 2016              | collection           |
| C          | Compreendendo a Física | Gaspar             | ATICA 3rd edition | Least chosen         |
|            |                        |                    | 2016              | collection           |

Next, we present one example of each function, all extracted from the collection B (Fukui et al., 2016).

3.1. Motivating function

An image assumes the motivating function when its only intention is to capture the student’s attention. Normally, the covers and the beginning of the units are made up of such images in which the narrative by itself is enough which enlightens the required content. In this case, a process of verb-iconic interaction is not established with supporting texts for a better understanding, as shown in Figure 2 which was used in the opening of the Kinematic unit.

![Figure 2: Example of a motivating image function](image)

3.2. Informative function

An Image assumes the informative function when it appears in the foreground of the didactic discourse. In this case, the image has the function of demonstrating situations in which the addressed physical concepts are applied. These images are connected to the context which relegates the explanation to the verbal discourse. Such images are present in textbooks to illustrate concepts, as shown in Figure 3, to explain the trajectory concept.
3.3. Explanatory function
The explanatory function is assigned when incorporating directional codes that aim to explain a process graphically. The use of these images in physics textbooks is common because they carry information that helps students obtain data for problem-solving related to physical applications. Figure 4 shows an example of explanatory function observed in a temporal sequence, used to demonstrate average scalar acceleration.

![Figure 4: Example of an explanatory image function](image)

3.4. Redundant function
An image assumes the redundant function when it transmits a message already clearly expressed by the written discourse. This type of image provides a visualization of the text described, reaffirming the text’s ideas, helping the student to perceive its meaning in an alternative way. Figure 5 was used to exemplify a redundant function with an experiment about mean scalar velocity.

![Figure 5: Example of a redundant image function](image)
In each selected physics textbook collection, we classified the images by their function, as proposed by Silva & Martins (2008). Table 2 shows the image distribution according to their motivating, informative, explanatory and redundant functions. The idea was to understand the image’s function profile and then, based on this, to choose images to produce equivalent interactive illustrations to complement, as an alternative, the textbook’s images. We were interested in verifying if images in motion facilitate the students learning when used as a strategy of teaching physics contents.

**Figure 5:** Example of the redundant image function
Table 2 The image function profile of the selected textbox

| Collection | A | B | C | Total | (%)  |
|------------|---|---|---|-------|------|
| Motivating | 3 | 2 | 4 | 9     | 4.0% |
| Informative| 45| 53| 17| 115   | 51.6%|
| Explanatory| 33| 40| 16| 89    | 39.9%|
| Redundant  | 5 | 4 | 1 | 10    | 4.5% |
| TOTAL      | 86| 99| 38| 223   | 100% |

We obtained the following: 52% of the images have an informative function and 40% of them have an explanatory function, while the redundant and motivating images sum up about 8%. As the informative function images were predominant in physics textbooks, we selected some of them to produce equivalent interactive images using the Illustrator software. These images appeared in the didactic discourse foreground, representing application situations of the physical concept addressed and tied to the context presented, which makes evident the authors’ concern to illustrate daily situations that can represent physical phenomena.

3.5. Illustrator Program

The Illustrator program enables us to adapt an image to create an illusion of motion by moving a sheet with specially printed vertical lines. We based our image treatment on the tutorial available at <https://www.youtube.com/watch?v=mwTcZPKVyi0>.

Once the adapted image has been produced by the Illustrator program, the movement can be observed by sliding the sheet over the image, moving it slowly from right to left (or vice versa). In fact, the vertical lines of the sheet will alternate the overlap between the hatch and the image, providing an illusion of movement. The following video shows well how the images move <https://www.youtube.com/watch?v=UW5bcwax78I>.

We choose four informative images from the kinematic unit and used equivalent interactive images reproduced by the Illustrator program that will be presented next.

Image 1: Figure 6 shows a textbook image used to demonstrate relative motion in the two frames of reference: the cyclist observing the wheel valve and a person standing on the sidewalk watching the cycle. Figure 7 is the equivalent image, produced by the Illustrator program, which gives the perception of movement.
Image 2: Figure 8 shows a textbook image used to illustrate the trajectory of a falling load in two frames of references: the pilot inside the plane and an observer in the ground reference. Figure 9 is the equivalent image, produced by the program which gives the perception of movement.

Figure 8: Trajectory of a box in two references

Figure 9: Equivalent Interactive image

Image 3: Figure 10 shows a textbook image representing the transmission of circular motion made by direct contact between three sprockets, which are used to prevent the wheels from sliding since the teeth fit into the grooves of the other wheels. During the contact, the direction of movement is reversed. Figure 11 is the equivalent image produced by the program and gives the perception of movement.

Figure 10: Image of circular motion transmission

Figure 11: Equivalent Interactive image

Image 4: Figure 12 shows a textbook image representing an oblique launch movement in which an athlete throws a basketball into the basket. Figure 13 is the equivalent image produced by the program which gives the perception of movement. In fact, the interactive image allows the student to visualize distinct moments of the movements and observe that the ball is raised to a maximum height and falls forming a parabola and that the time the ball takes to rise is equal to the time to go down.

Figure 12: Image of an oblique launch movement
4. Data analysis
Table 2 shows the analysis of the 223 images found in the three books studied, from the kinematics units which includes the images contemplated in the exercises. The table shows that textbooks have many images. Among the analysed collections, the C textbook has the fewest number of images and textbooks A and B have approximately the same quantity of images. From this analysis, we realised that the textbooks have more informative function images, followed by explanatory, redundant, and motivating functions, respectively.

We used the images from the textbooks (Figures 6, 8, 10, and 12) and the ones produced by the Illustrator program (Figures 7, 9, 11, and 13), to carry out a study with 20 first-year high school students from a public school in Santa Luzia city, located in the metropolitan region of Belo Horizonte, MG, Brazil. After a lecture on kinematics, addressing physics concepts, two questionnaires were applied for comparison purposes. The first questionnaire was illustrated with original images extracted from the textbooks and the second one with similar images generated by the Illustrator software.

Both questionnaires, A and B, focuses on the same questions, about the movement direction (Question #1) and the trajectory of an object (Questions #2, #3, and #4). The questions consider the two sets of images mentioned before (A: Figures 6, 8, 10, and 12) and (B: Figures 7, 9, 11, and 13). The analysis of the questionnaires, A (without interactive images) and B (with interactive images) are shown per question in Table 3 below by comparison between correct answers.

| # (Question type) | % Quest. A (Figure #) | % Quest. B (Figure #) |
|------------------|-----------------------|-----------------------|
| 1 (movement direction) | 55% (Figure 10) | 75% (Figure 11) |
| 2 (trajectory) | 90% (Figure 12) | 90% (Figure 13) |
| 3a (trajectory from airplane) | 65% (Figure 8) | 70% (Figure 9) |
| 3a (trajectory from earth) | 75% (Figure 8) | 75% (Figure 9) |
| 4 (trajectory) | 0% (Figure 6) | 25% (Figure 7) |

Table 3 shows that the differences are more accentuated in questions 1 and 4, both indicate a 25% greater difference in favour of questionnaire B. The two questions require the understanding of a circular motion of a gear system that includes known difficulties of movement perceptions. In fact, in question number 4 seven people (35%) did not understand it in questionnaire A. This question carried with it the image of a cyclist and this image showed the trajectory of two references: in the first one, an observer saw the cyclist from the sidewalk and the second considers the cyclist himself. The question asked about the trajectory of a certain point of the wheel according to both references. Although the interactive image
was presented, four people (57%) still did not understand the question in questionnaire B. This allows us to infer that a single presentation of an interactive image may not be enough to eliminate the difficulties of movement perception.

Finally, we emphasize the students' motivations regarding interactive images; what was addressed with the following question at questionnaire B: "Did the interactive images facilitate the question understanding?". Next, we will detail the students' responses.

Eighteen people (90%) answered that the interactive images facilitate the movement understanding, three people (15%) considered that the interactive image shows the movement direction, and two people (10%) responded that the interactive images make things clear. In addition, eight people (40%) expressed improved understanding with the use of images without mentioning their motives.

As for the possibility of "seeing" the movement, three people (15%) answered that the interactive image shows the trajectory of objects and one person (5%) answered that the interactive image shows a movement that "looks real". Does the fact of "looking" real indicate that "reality" shows a different movement from the presented movement?

Finally, it is important to reaffirm the relation of the theoretical reference adopted in this work with the results carried out by the research. Several questions answered by the interviewees are supported by authors, such as Frederico and Gianotto (2018) that, "Highlight the presence of social representation and subjectivity of students in front of interactive images."

Silva and Martins (2008) points of view are reiterated several times in the students' speeches. These authors, "Attribute to these images an important didactic and educational element for learning to take place". According to Gibin, Kiill and Ferreira (2009), "The images are few explored, and students present different understanding." These few explorations of the images in the classroom can be motivated by the lack of material and didactic resources mainly in the public school. We can also infer that students present differentiated intellectual and cognitive conditions that may be caused by the poor training and precarious living students' conditions. Beyond that, Rego (2011) assures that, "The images must represent the quotidian known by the student", and Martins (2010) also stresses the importance of "learning based on the relationship between scientific knowledge and everyday knowledge."

5. Final Considerations

Teaching and learning physics deals with work-in-process that gives meaning to reality. It means that students must understand what is communicated in verbal and symbolic languages, and be able to capture real phenomena. Our intention was to verify if the interactive images would facilitate students' physics understanding. In fact, we reached improvements in the correctness from questionnaire A (without interactive images) to B (with interactive images), and infer that the interactive image allowed a better students' understanding.

The interactive image has the purpose of facilitating student comprehension, and seeks to place the implicit information contained in the images explicitly, thus facilitates the student's understanding; but it is worth to reflect on the students' difficulty in analysing an image and extracting information that is not always explicit.

In this way, we finish this work with some new questions. The first question concerns the teaching and learning conditions that are related to training and precarious living students’ conditions. As pointed out earlier, students' social and educational trajectory interferes with their ability to absorb knowledge.

We also point out some limitations of the interactive image role to promote teaching and learning. In fact, a single introduction of an interactive image may not be enough to eliminate the difficulties of perceiving movement. We infer that sometimes to acquire acknowledgment seems to be much more linked to someone’s trajectory than to the possibilities offered by any educational methodological resource.

Finally, we present a discussion about the importance of teacher training. When Silva and Martins (2008) highlight the image didactic functions, especially informative and explanatory, they emphasize the teachers’ qualification and preparation as a fundamental condition for the accomplishment of the
proposed didactic image functions. These questions are considered as additional possibilities of reflections in order to improve physics learning and teaching.

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