



# Teaching Polarization through Cartoons

- Enseñanza de la polarización a través de historietas
- Ensino da polarização através de quadrinhos

## Abstract

This article presents the analysis and results of an investigative experience related to the teaching of polarization through cartoons. It is a qualitative approach and it involves the design and validation of a didactic sequence based on guided research principles. The proposal includes the making of three cartoons entitled: "The One Direction Car", "3D Cinema" and "Anti-Spy Cell Phone Screen", all of which are experimental design and model building exercises. The process was documented on the student-designed handbooks and the teacher's field journal.

The sequence helped to generate questions in the students about polarization, and it promoted the development of action plans to address the situations proposed in a theoretical-practical manner. The process helps to understand the meanings attributed to the polarization phenomenon in line with the characterization of light as a wave, the behavior of light in relation to materials and processes of 3D image composition. Some considerations about the importance of using cartoons while teaching physics are also described.

## Keywords

physics; polarization; teaching; cartoons; guided research

## Resumen

Este artículo presenta el análisis y resultados de una experiencia investigativa, en relación con la enseñanza de la polarización por medio de historietas. El enfoque es de carácter cualitativo e involucra el diseño y validación de una secuencia didáctica basada en principios de investigación orientada. La propuesta incluye la construcción de tres historietas tituladas: "El carro de 'One Direction'", "El Cine 3D" y "La pantalla anti-espía del celular", ejercicios de diseño experimental y de construcción de modelos. El proceso se documentó a través de cartillas diseñadas por estudiantes, y el diario de campo docente.

La secuencia favoreció la generación de preguntas en estudiantes acerca de la polarización, además de promover el desarrollo de planes de acción para abordar de forma teórico-práctica las situaciones planteadas. A través del proceso se comprenden los sentidos atribuidos al fenómeno de polarización en consonancia con la caracterización de la luz como onda, el comportamiento de la luz en relación con los materiales y los procesos de composición de imágenes en 3D. Adicionalmente, se describen algunas consideraciones sobre la importancia del uso de historietas en la enseñanza de la física

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Palabras clave

física; polarización; enseñanza; historietas; investigación orientada

### Resumo

Este artigo apresenta a análise e resultados de uma experiência investigativa em relação com o ensino da polarização por meio de quadrinhos. A abordagem é de caráter qualitativa e envolve o planejamento e a validação de uma sequência didática baseada em princípios de investigação orientada. A proposta inclui a construção de três quadrinhos intitulados: “O carro de ‘One Direction’”, “O Cinema 3D” e “A película anti-espião do celular”, exercícios de desenho experimental e de construção de modelos. O processo foi documentado através de cadernetas elaboradas pelos estudantes e o diário de campo do professor.

A sequência favoreceu a geração de perguntas em estudantes acerca da polarização, além de promover o desenvolvimento de planos de ação para abranger de forma teórico-prática as situações descritas. Através do processo é possível compreender os sentidos atribuídos ao fenômeno de polarização em consonância com a caracterização da luz como onda, o comportamento da luz em relação com os materiais e os processos de composição de imagens 3D. Adicionalmente, foram descritas algumas considerações sobre a importância do uso de quadrinhos no ensino da física.

Palavras chave

Física; polarização; ensino; quadrinhos; investigação orientada

## Introduction

Herein are the results of “Teaching Polarization through Cartoons/Comics” that was developed with a High School group of students in Bogotá, Colombia. The research methodology allowed to design and validates a didactic sequence based on Oriented Research. This process was accompanied by the development of seven questions related to three stories: “One Direction’s car (OD)”, “3D Films (3D)” and “Anti-spy cellular screen or filter (AF)”. Findings are organized by content analysis, enabling students to become aware of Polarization phenomenon that is consistent with the characterization of light as a wave, behavior of light in relation to the materials, and processes of composing 3D images.

## Theoretical Framework

Within the academic realm of physics, students are confronted with major challenges associated with conceptual constructions and development of scientific skills. Such skills include: proposing problems, formulating hypotheses, discussing their observations, testing their hypotheses as well as coherently organizing and systematizing the results (Verdú, Martínez-Torregrosa & Osuna, 2002, quoted in Guisasaola, Zubimendi, Almudí & Ceberio, 2007). Additionally, in many cases students work under the assumption that physics is boring and unaligned with their interests. In this regard, Valdés and Valdés (1999) suggest that the process of learning physics is linked to research activities, where it is essential to familiarize students with the culture of contemporary society. In turn, García R. (2009) links science teaching and learning through comic strips in high-school courses, characterized by having familiarity with the students’ everyday life, to allow discussion around them and being interesting for students. Moreover, Mualem and Eylon

(2007) included images of everyday situations when teaching Newton’s laws, allowing the laws to be analyzed from different qualitative categories, these images and analysis raised upon, contributed to understanding of physical concepts related to students’ daily lives.

Perales and Vilchez (2002) included Pokemon and The Simpsons in physics teaching, with the objective being to raise in students’ minds doubts about situations that appear contrary to the laws of physics, such as the force of gravity and Newton’s laws, among others. Other methods suggested by Adam and Sztrajman (1992) include the paradoxical situations, dramatization of physical processes, physical myths, transgressions to physics concepts in cartoons and physical considerations in artwork. Similarly, Rogers (2007) notes that films contain situations which can be analyzed in the light of physical phenomena; situations that are deemed as true for viewers are, for students, questionable, and “students can formulate hypotheses around these situations in order to explain what is being perceived” (p.38). In this particular case, students observe films, such as Matrix and Road Runner & Coyote, and meet to discuss the situations presented, classifying and analyzing them as real or unreal from the point of view of physics. At the end of each session, teacher listens to the student’s analysis and then concludes that students are showing a more scientific construction of each interpretation (Rogers, 2007). Complementary, Gallego (2007) investigated how language used in comics contributes to the image of science distortion that students have, and how the stories presented directly relate to scientific themes and reflect science popular image transmitted by different media. In this regard, he proposes to replace these concepts with others more aligned with current epistemological conceptions and which contribute to a better understanding of scientific situations.

Although, all these articles analyzed learning of physics through commercial comics and they do not provide specific cartoons for educational purposes. Hence, the present article attempts to contribute to develop teaching researches in which teachers and researches design, validate and apply specific comics strips, cartoon or comic books with the sole purpose of teaching physics themes.

## Rationale and Purpose

Based on physics teaching from alternative perspectives and the oriented research reference framework, the implementation of a didactic sequence based on polarization is investigated in three contextual situations: Polarized car windows (Window Tint), 3D cinema, and the anti-spy cell filter. The focus of this work was to investigate how Oriented Research contributes to the understanding of polarization by a group of students through seven key questions.

## Oriented Research (OR)

For Gil (1983) Oriented Research (OR) is a response to the search for a new paradigm of science education, which is consistent with the scientific method -where students relate, differentiate and incorporate existing concepts into an inclusive dialogue, which they are then able to build. The OR is a methodology with a constructivist approach characterized by considering students' ideas, not as part of the explanation of the phenomenon but as sources of imbalance in their system of ideas.

In Europe, Abril, Ariza, Quesada and García (2014) identified OR as "Inquiry Based Learning" (IBL), a suitable methodology to improve natural sciences and mathematics teaching, as it encourages students to find their own explanations, improve their understandings of natural phenomena and content, as well as develop skills such as inquiry, hypothesis formulation and verification or refutation of such hypothesis.

Some key aspects that must be considered in designing experiences that encourage students to research and to put aside the idea that such research is an activity solely for scientific scholars are highlighted by the sequence shown in figure 1. The process involves the organization of activities, which should initially create opportunities for inquiry and formulation of problems related to students' interests, they then investigate with the use of prior information about the problem or situation of interest and promote a reworking of the initial knowledge from hypothesis or possible explanations. In conclusion, students should establish the relationship between the previous information and the new information that has built to be applied in other situations, and share their findings or conclusions with others.

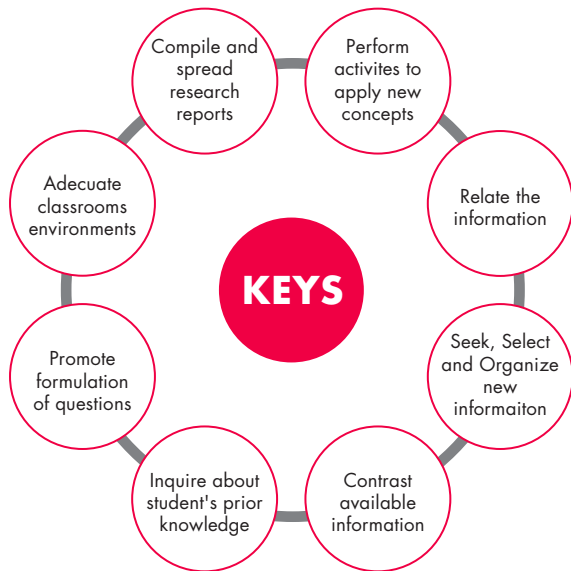


Figure 1. Keys to design experiences with the OR framework.

## Method

The developed methodology was of the qualitative kind and interpretive manner. For data analysis, OR methodology was used -under which an approximation of how students construct explanations and give responses to situations of their interest is performed, establishing a relationship between the OR methodology phases (Vega, 2011) and the students' responses. This methodology makes it possible to identify modeling, to interpret the relationships that exist between new information and previous information within the context of comics (García & Criado, 2007).

Activities with students were developed in two main phases. The first consisted of a diagnosis to define everyday situations for students with the polarization of light. In the second phase, construction of the action plan was developed in four stages (see figure 2).

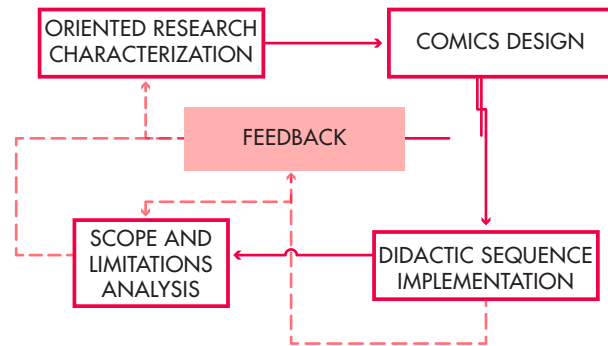


Figure 2. Stages of innovation work plan.

## Data Collection and Analysis

The following section presents a summary of the analysis on students' set of responses to each of the activities about their observations of the comic and the process of polarization (see Annex 1, 2 and 3). This analysis looks for detecting the possibilities offered by the OR for polarization teaching.

**Q1: What do you think will happen next in the story? What sort of questions or situations does the story presented generate in you?**

In summary, the first question served as an indicator of interests and expectations students might have, and allowed the researcher to know the different ideas that students brought up after they relate them to a context. At first, students attempt to relate their individual socio-cultural aspects with the comic and that is why most of the questions contain such factor. Therefore, concerns associated with a physical phenomenon pass to a second order. Only in two opportunities, situations related to the polarization of light were explained.

The other aspect displayed reflects students' intention to continue using cartoon images designed by themselves or simple two or three-line wordings within the sequence. Figures 3 and 4 are two samples of the comics

produced by students that used the original drawings, however the story continuity it is not clear from the students' perspective. These constructions are based on the students' common sense and there are dialogues and explanations as a reference. Figure 4 indicates the lack of knowledge about the main topic addressed by the comics and it is therefore very difficult to think of a possible continuation.

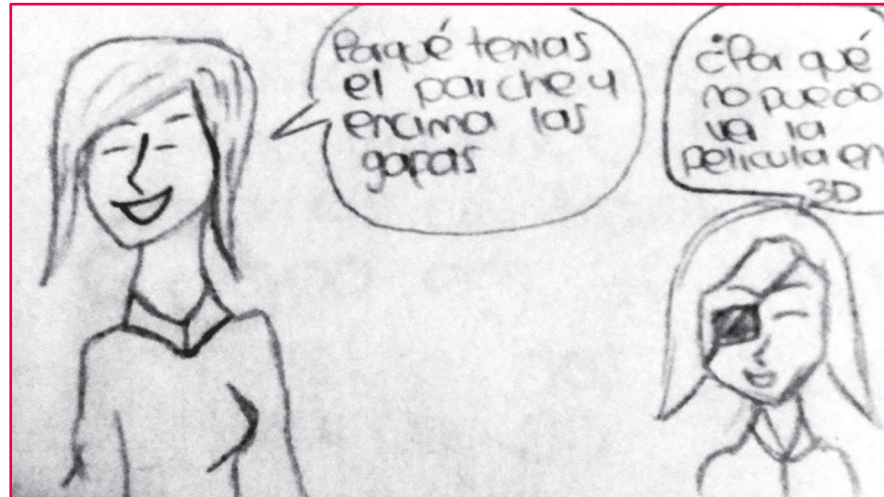


Figure 3. Story continuity as per G2: Sample of aftermath results based on Comic 2, Cinema 3D, Annex 2. (Text: *Girl on the right: "Why I can't see the movie on 3D?". Girl on the left: "Because you had the eye patch and wore the glasses over".*)

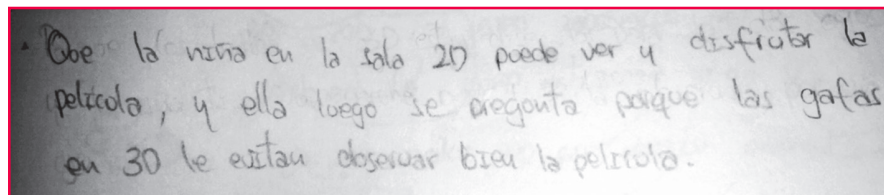


Figure 4. Story continuity as per G6: Sample of aftermath results based on Comic 2, Cinema 3D, Annex 2. (Text: *"The girl in the 2D room can see and enjoy the movie, then she asks herself why the 3D glasses did not allowed her clearly watch the movie."*)

## Q2: After defining the questions and situations, discuss with the teacher and register the agreements reached.

The groups receiving OD comic agree to inquire into the circumstances surrounding the visibility from inside the limo and not from outside. On the other hand, G1, G4 and G9 focused their attention on the role of the filter. G9 is intended to determine what physical characteristics the filter has that influence the polarization effects; G4 investigates the nature of filter materials and then shares that information with others.

Finally, in table 1, G1 ascertains the physical phenomenon involved in the filter operation, which differs from the G9 question as it relates to the environment.

G2, G6 and G8 expressed their concerns about the influence of the human eye's perception of the 3D image: G2 is interested in the difference between conventional lenses and those used for viewing a 3D movie. For G6 it is crucial to know how vision is limited to a single eye to the point of preventing the movie from being displayed in 3D; and finally, G8 wants to validate the aforementioned in the comic.

**Table 1. Questions selected by the students**

Group	Question
G1 (AF)	What physical phenomena are involved in the operation of the filter?
G2 (3D)	What do 3D glasses have that normal lenses don't have?
G3 (OD)	Why is it not possible to see inside the limo from the outside?
G4 (AF)	What material is used to make the anti-spyware filter?
G5 (OD)	Why is it possible to see through polarizing windows from inside out and not outside in?
G6 (3D)	Why the Girl (2) cannot see with the 3D vision glasses?
G7 (OD)	How to differentiate a one-way glass from a normal one, considering the effects of light?
G8 (3D)	Can you see in 3D with one eye?
G9 (AF)	What physical features does the filter have?
G10(OD)	What makes it possible to see from inside the car and not from the outside?

Source: The authors

### Q3: What do you understand based on the agreement with the teacher?

This question provides recognition of the students' knowledge regarding understandings of the problem and facilitates some more complex processes. The first is the graphical representation of light, which varies among students, as some of them employed solid lines, dotted lines and rays, and all had the same intention: to represent the light that was interacting in the situation. It was necessary to have a reading with each individual group about the guiding questions that were prepared to conduct the

development of each question. This was followed by a continuous inquiry for the researcher to clarify the students' positions. For each of the students' statements, questions were formulated to enrich their investigative process.

About the use of examples and real-life experiences, which were developed by the students, the overall experience was positive as it broadened the discussion of the subject matter and enriched groups' constructions with new questions and conjectures. It was evident how students turned to everyday life situations to relate them to issues spoken about in class.

### Q4: Which could be the answers or solutions to the situation you proposed?

The responses to this question were very brief and superficial. As García A. mentioned, intuitive knowledge prevails in the students over scientific knowledge and it is for this reason that their hypotheses and conjectures are based on their personal experiences. They pretend to test their ideas (Furió, Azcona & Guisasola, 2006) to reaffirm what they understand about the problem. Also, some groups consider it to be necessary to consult theories from textbooks or the Internet to clarify their own theories to avoid falling into errors when being heard.

### Q5: What procedures, processes or methodologies would you develop to give a solution to the agreed situation?

The students recognize that solution procedures should be grounded in a research that allows them to have knowledge of the subject and then address other aspects such as design models or prototypes. Within some groups the lack of clarity on process development is evident, however, there is also an acceptance

that they ignore many physical factors surrounding the situation presented by the comic. Some clear proposals raise the question of how to display their answers, whether through speech, videos or demonstrations.

### Q6: How do you plan to release your results and conclusions?

Most groups considered it appropriate to develop explanatory presentations using audio-visual aids, while some students preferred to show models or prototypes built by themselves to facilitate their peers' comprehension (see figure 5). Another communication strategy is based on video editing or graphic material, accompanied by an explanation. It should be noted that not all student's plans were executed in their entirety, due to factors like inconveniences in materials, costs and physical spaces within the institution.



Figure 5. Handmade carton-board model of the Limousine, Cartoon 3, Annex 3.

### Q7: Solution or Answer

All groups built up a solution to their problem through various strategies and theories of the nature of light. Using group's capabilities, they validated and rethought their hypotheses and ranked their ideas by replacing intuitive concepts for more scientific approaches.

That is how students achieved their objective as they applied their own research methods to answer a situation proposed by themselves. As far as opportunities for discussion and feedback were generated, explanations were evidently satisfactory to validate the ideas exposed by the groups.

### Discussion and implications

Suggesting new questions became an incentive for students because allowed them to recognize that their search methods were not completely effective and

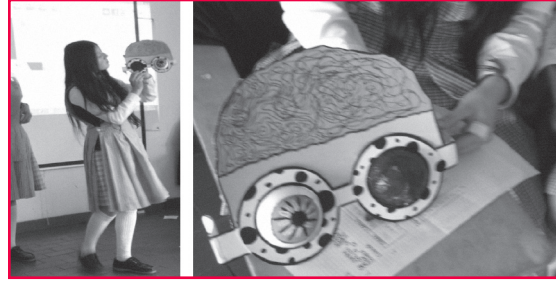


challenge them to left behind less useful theories and reconstruct their hypotheses. Similarly, there are indications of relationships with other sciences such as biology, medicine, chemistry and philosophy, which supported the conjectures of students.

There was a desire within the groups to validate their assumptions and, therefore, propose new satisfactory strategies with the new information. To accomplish such desire, groups developed and constructed models of the limousine, the 3D-glasses and the spy screen using basic and available materials. See figures 6A, 6B and 7A, 7B. As the models were completed, students could analyze and reinforce their conjectures. Another important aspect to mention is that students read and gathered more related information about the study subjects, therefore their responses were more structured and balance.

Innovating in the classroom with the use of comics and Oriented Research is not directed towards providing students with a recreational activity but rather tasking the students to analyze situations; neither to use the situations as motivational elements, and then return to the old fashion way of teaching strategy. The actual work consists of forcing students to question their own ideas, which were formulated from within their personal environment, and which can be graphically presented in a visually pleasing way (built with their help). It is possible to give students the opportunity to act, feel and think as researchers, with the ability to build and validate their ideas, understanding that research is not an exclusive activity for scientists or only possible to develop in laboratories.

In the case of polarization of light, students correctly related the three situations proposed with the wave phenomenon. Moreover, they were aware of other unforeseen phenomena indirectly involved in the situation, indicating



Figures 6A and 6B. Handmade model of the 3D-Glasses, Cartoon 2, Annex 2.



Figure 7A. Handmade model of the limousine, Cartoon 3, Annex 3.



Figure 7B. Handmade model of black box based on Cartoon 2, Annex 2.

connections between existing and new knowledge. To validate their conjectures, students relied on the use of regular real-life experimentations. Ultimately, students were not aware of the process of polarization of light but were aware of the realities that are explained because of the behavior of light.

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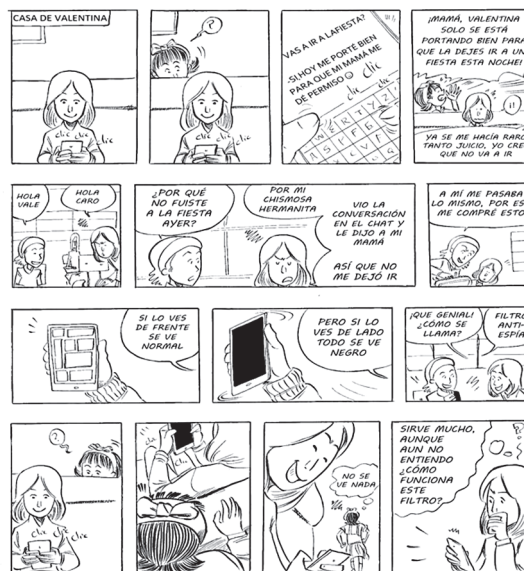
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### Annex 1. Comic 1. Anti-spy filter

VALENTINA'S HOUSE
Girl 1 (Valentina): Click, Click, Click
Girl 2 (Valentina's little sister): "?"
On the cell- Chat: -Are you going to the party? -Girl 1: Yes, I have been a good girl today so mom would let me go.
Girl 2: " Mom! Valentina is behaving well for you to let her go to a party tonight!"
Mom's voice: I was surprised of such a good behavior; I think she is not going.
At school:
Girl 3 (Valentina's classmate): Hi, Vale.
Girl 1: Hello, Caro.
Girl 3: Why you didn't go to the party yesterday?
Girl 1: Because of my gossip little sister. She saw my chat conversation and told my mother. So, she didn't let me go.
Girl 3: It also happened to me, therefore, I bought this!!!
Girl 3: If you look right at it, it seems normal. But if you look at it on a side, it looks black.
Girl 1: That's great! How is it call?
Girl 3: Anti-spy filter.
At home
Valentina: Click, click, click.
Girl 2: "?"
Girls 2: "I cannot see anything"
Valentina: It helps a lot. However, I still do not understand how this filter works?



### Annex 2. Comic 2. Cinema 3D

AT THE CINEMA
Girl 1: Is this the first 3D movie you see?
Girl 2: Yes!
Girl 3: You are going to love it!!
SIGN: "SUNGLASSES OR PATCHED ARE NOT ALLOWED"
Clerk: Ja, ja, ja...Please come in.
Girls: Thank you.
Announcement: "PLEASE PUT YOUR GLASSES ON"
Screen: "RRRRR" "RRRRR"
Girl 2: "I believe my glasses doesn't work"
Girl 3: Try mines!



Girl 2: Thanks.
Girl 2: No, this one neither!
Girl 2: Do you see it properly?
Girl 1: Yes!!
Girl 3: Of-course!
Clerk: Ja, ja, ja.
SIGN: 2D films
Girl 2: Here I can see it well!
Girl 2: I wonder. Why I couldn't see the movie in 3D?

### Annex 3. Comic 3. One Direction Car

EL DORADO AIRPORT	
Boy 1: It was a long trip	
Boy 2: Hurry up. The limousine is awaiting.	
Boy 3: Yes, let's see our fans.	
On the limousine and outside in the street: They are there!!!... "Ayyyy!"... "Oh my God!"	
Girl 1: Here. Here!	
Girl 2: I love you	
Girls 3&4: "Heyyyy"	
Boy 2: Say "Hello" boys.	
Boy 3: Hi!	
Girls: (Confused and surprised) "¿?"	
Boy 2: What happened?	
Boy 3: Why the girls are angry?	
Boy 1: Can't they see us?	
Girl 1: "They are rude"	
Girl 2: "Listen"	
Girl 3: "Roll-down the window at least"	
Boy 1: Let's try this	
Boy 2: Hi, Girls	
Girls: "There they are! Hello!! How handsome are they!!"	
Boy 1: How strange. They didn't see us until we lowered the glasses.	
Boy 2: We saw them through the window.	
Boy 4: How strange	
Boy 5: Perhaps the windows are (were) dirty.	

