

The Documentary Cave of Forgotten Dreams: Activities in Teacher Training in Physics

Aldo Aoyagui Gomes Pereira

Professor at the Federal Institute of Education, Science, and Technology of Sao Paulo – Piracicaba campus

E-mail: agpereira980542@gmail.com

Maria José Pereira Monteiro de Almeida

Professor of the Graduate Program in Education and Science and Mathematics Teaching at the University of Campinas

E-mail: mjpmalmeida@gmail.com

Abstract: In this study, we engaged four undergraduate students of a physics course in a set of activities using the documentary *Cave of forgotten dreams*, produced and directed in 2010 by Werner Herzog. In these activities, we discussed how the carbon-14 dating of the cave paintings depicted in the documentary has influenced the field of archaeology. In addition, we problematized some aspects of the students' interpretation of the images and narrative of the documentary. The information analyzed was collected through video recordings and the written production of the undergraduates. The analysis was based on the concepts and principles of Discourse Analysis as appear in texts of Eni Orlandi published in Brazil. We noted that, in the students' view, the use of documentaries in the classroom is associated with the idea of visualization, reinforcement, and illustration. During the activities, however, we observed their intention to interpret critically the images and narrative in the documentary.

Keywords: documentary; teacher training; radiocarbon dating; discourse analysis; Chauvet Cave.

Resumo: Neste trabalho desenvolvemos um conjunto de atividades com quatro licenciandos de um curso de física utilizando o documentário *A caverna dos sonhos esquecidos*, do diretor alemão Werner Herzog, produzido em 2010. Nessas atividades, discutimos por que o uso da datação por carbono 14 nas pinturas rupestres retratadas no documentário causou impacto na área arqueológica. Além disso, problematizamos alguns elementos da leitura de imagens e a narrativa desse documentário. A coleta de informações se deu por meio de gravações em vídeo e da produção escrita dos licenciandos. A análise foi realizada a partir de princípios e noções da Análise do Discurso, principalmente através de textos de Eni Orlandi publicados no Brasil. Durante a realização das atividades destacamos a intenção dos licenciandos de realizar leitura crítica de imagens em movimento e da narrativa contida no documentário utilizado.

Palavras-chave: documentário; formação de professores; datação por carbono; análise de discurso; caverna de Chauvet.

Received: 04/24/2017

Approved: 07/19/2017

1. INTRODUCTION

It is current consensus that research aimed at introducing Modern Physics (MP) topics to Secondary Education (SE) students should not be elaborated in the same way as Classical Physics (CP) is treated in this education level^{1,2,3}. One aspect that we find important to discuss during classes is how MP has influenced and was itself influenced by other knowledge areas and disciplines, like chemistry, biology, archaeology, arts, etc.

Since MP is a current topic with applications that are present in our daily lives, MP applications are often remembered in Science Documentaries (SD). Recent studies, however, finding that when these resources are utilizing in the classroom contexts they have the purpose of motivating, illustrating and reinforcing the apprehension of scientific topics⁴. We consider that SD use in the classroom should go beyond these goals to discuss, for example, how such scientific topics are transmitted. Additionally, researchers have identified the potential of this kind of resource to discuss questions related to the nature of science and to further social and scientific debates in SE science classes^{5,6}.

The relationship between science documentaries and its classroom use enables the creation of a space of discussion that can contribute to a more comprehensive analysis of the scientific process and the process of knowledge building⁷.

In this study, we investigate the process of production of meaning of four physics undergraduate students during learning activities using the documentary *Cave of Forgotten Dreams*⁸, produced and directed in 2010 by the German director Werner Herzog. The guiding question of our study was: how the learning activities performed using the documentary can contribute to develop and broaden the students' perception about the introduction of physics topics in secondary education. In this case, carbon-14 dating.

Herzog's documentary begins relating the discovery of a cave in southern France, in December 1994, by three speleologists: Jean-Marie Chauvet, Éliette Brunel, and Christian Hillaire. Today the cave is known as Chauvet Cave, honoring the first discoverer. Inside the cave, researchers found a series of wall paintings, approximately 400 in all. One aspect responsible for the importance of the discovery was the controversy over the paintings dating.

[...] while the age estimate of its magnificent paintings, made by Jean Clottes shortly after its discovery, based on the first stylistic data obtained, situated them in the Solutrean (21,000 to 18,000 years before present), direct radiocarbon dating of one of the most spectacular drawings – the rhinoceros combat – indicated results of 31,000 years before present. The difference was of the magnitude of 10,000 years!⁹

The technique of carbon-14 dating caused a significant change in archaeology fieldwork methods and, in the case of Chauvet Cave paintings, surprised archaeologists because of the 10,000 years discrepancy with the first dating using traditional archaeological methods.

1. REZENDE JUNIOR, Mikael Frank; CRUZ, Frederico Firmo de Souza. Física moderna e contemporânea na formação de licenciandos em física: necessidades, conflitos e perspectivas. *Ciência & Educação*, Bauru, v. 15, n. 2, p. 305-321, 2009. Disponível em: <<http://www.scielo.br/pdf/ciedu/v15n2/a05v15n2.pdf>>. Acesso em: 24 abr. 2017.

2. COSTA, Rodrigo Ronelli D.; NASCIMENTO, Robson; GERMANO, Marcelo Gomes. Salvador Dalí e a mecânica quântica. *A Física na Escola*, v. 8, n. 2, p. 23-26, 2007. Disponível em: <<http://www.sbfisica.org.br/fne/Vol8/Num2/v08n02a06.pdf>>. Acesso em: 24 abr. 2017.

3. LOBATO, Teresa; GRECA, Ileana Maria. Análise da inserção de conteúdos de teoria quântica nos currículos de física do ensino médio. *Ciência & Educação*, Bauru, v. 11, n. 1, p. 119-132, 2005. Disponível em: <<http://www.scielo.br/pdf/ciedu/v11n1/10.pdf>>. Acesso em: 24 abr. 2017.

4. RAMOS, Mariana Brasil; SILVA, Henrique César. Educação em ciência e em audiovisual: olhares para a formação de leitores de ciências. *Cadernos CEDES*, Campinas, v. 34, n. 92, p. 51-67, jan./abr. 2014. Disponível em: <<http://www.scielo.br/pdf/ccedes/v34n92/a04v34n92.pdf>>. Acesso em: 24 abr. 2017.

5. BARBOSA, Leila Cristina Aoyama; BAZZO, Walter Antônio. O uso de documentários para o debate ciência-tecnologia-sociedade (CTS) em sala de aula. *Revista Ensaio*, Rio de Janeiro, v. 15, n. 3, p. 149-161, 2013. Disponível em: <<http://www.scielo.br/pdf/epec/v15n3/1983-2117-epec-15-03-00149.pdf>>. Acesso em: 13 jun. 2017.

One important point that motivated us to choose Herzog's documentary is that it does not follow the classic SD scheme. Its narrative does not just aim to inspire the viewer to search for "scientific truth", but also aims to leave the viewer in a state of constant reflection on the consequences of the discoveries made in the cave. As pointed out by Leão¹⁰, the interviews made do not highlight just the scientific content.

The director's choices make it clear that the scripting of each story goes beyond a mere technical explanation of the subject: there is a search for an intimate view of history and of the singularity of each topic, and how this trait can contribute to illuminating the whole of what is being researched.

In fact, the narrative, the interviews, the dialogues, the framing of images, the soundtrack, etc, evoke discussions and debates that surpass the explanations of the scientific concepts underlying the cave paintings discovery. Of course, we would not know much about the paintings without scientific procedures. Using imagination and creativity, however, we can learn a lot more beyond its age, as determined by carbon-14 dating technique. Herzog's documentary can help bringing to the classroom a critique of the classical method of scientific explanations that¹¹

tends to reduce the knowable to the manipulable. Today, it's necessary to strongly insist on the usefulness of a knowledge that can serve reflection, contemplation, discussion, and apprehension by everyone, each one with her own knowledge, experience, and life.

Besides reflecting upon the carbon-14 dating technique impact on the dating of the paintings in question, we also discussed with the undergraduates how the relationships between science and art appeared in this audio-visual resource by analyzing the elements present in the documentary's imagery and narrative.

2. THEORETICAL APPROACH AND PRODUCTION CONDITIONS

In this study, we based our theoretical and methodological approach on Discourse Analysis (DA) methods and discussions. We relied mainly on works published in Brazil by Eni Orlandi. Coherently with this approach, we considered the principle of non-transparency of language and the following concepts: anticipation mechanism, repetition, discursive memory and authoritarian and polemic discourse.

The principle of non-transparency of language states that looking for a single meaning in an [audio-visual] narrative is an illusion. The narrative will always be traversed by other meanings, informed by history, social context, and, hence, by ideology and the unconscious.

In the case of the anticipation mechanism, the subject assumes the interlocutor's place, predicting how the other will "interpret" his words. The subject anticipates the meanings that the interlocutor will attach to her words.

6. REID, Grace. The television drama-documentary (dramadoc) as a form of science communication. *Public Understanding of Science*, v. 21, n. 8, p. 984-1001, 2012.

7. GUERRA, Andreia; MORAIS, Angelita. História e a filosofia da ciência: caminhos para a inserção de temas física moderna no estudo de energia na primeira série do Ensino Médio. *Revista Brasileira de Ensino de Física*, São Paulo, v. 35, n. 1, p. 1502-1511, 2013. Disponível em: <<http://www.scielo.br/pdf/rbef/v35n1/v35n1a18.pdf>> Acesso em: 24 abr. 2017.

8. Título original: *Cave of forgotten dreams*. Diretor: Werner Herzog. Roteiro: Werner Herzog. Intérprete: Werner Herzog. EUA: History Films, 2010. (90 min). Disponível em: <<https://www.youtube.com/watch?v=IzcregYsle4&t=14s>>. Acesso em: 4 jun. 2017.

9. CABRAL, João M. Peixoto. *A radioatividade: contributos para a história da arte*. Lisboa: IST, 2011, p. 312.

10. LEÃO, Rita de Cássia da Silva. *Werner Herzog em busca da compreensão humana*. 2015. Tese (doutorado em ciências sociais) – Departamento de Antropologia, Pontifícia Universidade Católica de São Paulo, São Paulo, 2015, p. 87.

11. MORIN, Edgar. *Ciência com consciência*. Rio de Janeiro: Bertrand Brasil, 2010, p. 30.

12. ORLANDI, Eni L. Puccinelli. *Análise de Discurso: princípios & procedimentos*. Campinas: Pontes, 2010, p. 73.

13. Idem, p. 74.

14. Idem, p. 76.

15. ALMEIDA, Maria José Pereira Monteiro de. *Discurso pedagógico e formação de professores das ciências da natureza: foco no professor de física*. Alexandria, Florianópolis, v. 5, n. 2, p. 29-41, set. 2012. Disponível em: <<https://periodicos.ufsc.br/index.php/alexandria/article/viewFile/37712/28886>>. Acesso em: 13 jun. 2017.

16. ORLANDI, Eni L. Puccinelli. *A linguagem e seu funcionamento: as formas do discurso*. São Paulo: Pontes, 2001. p. 26.

17. XAVIER, Ismail. *O olhar e a cena: melodrama, Hollywood, Cinema Novo*, Nelson Rodrigues. São Paulo: Cosac & Naify, 2003, p. 32-35.

18. BRUZZO, Cristina. *O documentário em sala de aula*. *Ciência & Ensino*, São Paulo, v. 4, p. 23-25, 1998. Disponível em: <<http://prc.ifsp.edu.br:8081/ojs/index.php/cienciaeensino/article/view/32/39>>. Acesso em: 24 abr. 2017.

19. DIJCK, José Van. *Picturizing science: the science documentary as multimedia spectacle*. *International Journal of Cultural Studies*, v. 9, n. 1, p. 5-24, 2006. Disponível em: <<http://journals.sagepub.com/toc/icsa/9/1>>. Acesso em: 14 jun. 2017.

20. LEÓN, Bienvenido. *Science on television: the narrative of scientific documentary*. Bedfordshire: Pantaneto, 2007.

This mechanism regulates the discussion, since it restricts what is being said, that is, it silences some statements by formulating others, depending on the interlocutor position, ranging in the spectrum from complicity to absolute antagonism¹².

Another concept used by us is of repetition, of which Orlandi¹³ distinguishes three interpretative modes or kinds: *empirical repetition* – mnemonic exercise that does not historicize what is being said; *formal repetition* – a technique for producing sentences, a grammatical exercise that also does not historicize, just organizes; *historical repetition* – a formulation that produces a meaning among the others in the discourse, inscribing what is being said on the constitutive memory, what is being said is historicized by means of examples and the relationships between the spoken and the unspoken.

We also used the concept of discursive memory. The discursive memory makes it possible to enunciate, as the memory recovers what was already said – through a pre-built formulation – and which is subjacent to what is speakable¹⁴. It is the discourse analyst role to search for indications that the immediate production conditions do not determine exclusively what is said, but also how memory appears in speech.

The concept of authoritarian discourse refers to the discourse in which the polysemy is restrained, the referent is obscured by the kind of language exchange that is established, and the speaker puts herself in the position of an exclusive producer of meanings and significations.

As to the polemic discourse, the polysemy is controlled and the referent is disputed by the interlocutors, which maintain themselves active in the exchange, in a relationship of tense dispute for meaning^{15,16}.

We believe that, by adopting this theoretical and methodological approach, we can develop learning practices that enable teachers to decentralize their roles as producers of meaning in the classroom, by prioritizing polemic discourse between them and the students in the classroom.

In our analysis of the undergraduates' discourse about the documentary's images and narrative, we used the works of Xavier¹⁷, Bruzzo¹⁸, Dijck¹⁹ e León²⁰.

The way we planned the activities using Herzog's documentary (including the choice of the documentary itself) was inspired by discussions in the field of science teaching about furthering a closer relationship between science and art in education^{21,22}. We consider that science education can be more meaningful to students by discussing in class the relationships between science and other cultural systems²³, like literature, music, cinema, theater, etc.

The context of the production conditions was as follows: the interviews analyzed in this study took place during the second half of 2012 in a public university of the State of São Paulo, in the course of Physics Teaching Practices II, part of the undergraduate in Physics degree program. The four undergraduate students interviewed were enrolled in the course, at the time attending the sixth semester of the program and the teacher responsible for the class is the first author of this study.

The readings required in the course aimed to present to students the concept of documentary language and its relationship to learning activities in the classroom. Among other texts, the students read a paper by Bruzzo²⁴ that questions the idea of a documentary as a faithful portrait of reality. We also read a work by Léon²⁵ that discusses some features of science documentaries.

Information gathering for our analysis took place during three sessions of activities, each taking around one hour and twenty minutes of duration. Our methodological approach involved the following activities: a) the reading of two texts on the topics discussed in the documentary; b) to watch the documentary; c) answering a questionnaire about the documentary; d) discussing the documentary content; and e) the students preparing their own set of questions about the subject of the documentary.

The texts mentioned in the item “a” were “A química do tempo: carbono-14” (The chemistry of time: carbon-14), published in the journal *Química Nova na Escola*²⁶, and “A caverna onde a arte nasceu” (The cave where art was born), from the magazine *Scientific American Brasil*²⁷. Both articles were assigned to extra-class reading a week before the documentary exhibition. The first one describes how carbon-14 dating technique works and shows some of its applications. The second one discusses the importance of the discovery of Chauvet Cave and its paintings for the field of archaeology.

Carbon occurs in nature in three isotopes: ^{12}C (98,89%), ^{13}C (1,11%) e ^{14}C ($^{14}\text{C}/^{12}\text{C} \approx 12^{-12}$ in living beings), of which only the last one is radioactive. Carbon-14’s half-life is estimated at 5,730 years, that is, it is the time that a certain amount of it takes to reduce to half. In 1949 Willard Frank Libby (1908-1980) and colleagues measured the decaying rate of carbon-14 in samples of wood and marine shells freshly collected at different parts of the earth and verified that results were almost equal for all of them. This showed that the amount of carbon-14 in living beings remained constant, regardless of their location²⁸. In plant tissue, for example, carbon-14 is incorporated by photosynthesis, through the conversion of CO_2 in organic compounds. Since the carbon exchange between plants and environment ends with their deaths, the amount of carbon-14 in the dead plant begins to diminish, following the half-life of this radioactive element. If we start a stopwatch at the time of a plant’s death, from that moment on the amount of carbon-14 will begin to decrease as follows: by half after 5,730 years; by one quarter after 11,460 years, and so on. We must keep in mind that the technique is only effective for the interval of 40,000 to 100,000 before present, due to the carbon-14’s 5,730 years half-life. This interval comprises the dates found in Chauvet Cave paintings. The dating was obtained by analyzing charcoal fragments contained in the paint used by the prehistoric painters.

In the class following the texts reading, we watched the documentary and then each student received five questions to be answered at home and handed back the following class. After receiving the answered questions, we had a 1 hour and 20 minutes long session of general discussion about the documentary. At the end of the discussion session, we asked the undergraduates to plan a learning

21. ZANETIC, João. *Física também é cultura*. Tese (doutorado em educação) – Faculdade de Educação, Universidade de São Paulo, São Paulo, 1989.

22. MARTINS, André Ferrer P. (Org.). *Física ainda é cultura?*. São Paulo: Livraria da Física, 2009.

23. ZANETIC, João. Física e Arte: uma ponte entre duas culturas. *Proposições*, Campinas, v. 17, n. 1, p. 39-57, 2006. p. 42. Disponível em: <<http://periodicos.sbu.unicamp.br/ojs/index.php/proposic/article/view/8643654/11171>>. Acesso em: 24 abr. 2017.

24. BRUZZO, Cristina. O documentário em sala de aula, op. cit.

25. LEÓN, Bienvenido. *Science on television*, op. cit.

26. FARIAS, Robson Fernandes. A química do tempo: carbono-14. *Química Nova na Escola*, n. 16, p. 6-8, nov. 2002. Disponível em: <http://qnesc.sbq.org.br/online/qnesc16/v16_A03.pdf>. Acesso em: 24 abr. 2017.

27. VALLADAS, Hélène; CLOTTE, Jean; GENESTE, Jean-Michel. A caverna onde a arte nasceu. *Scientific American Brasil*, São Paulo, n. 31, 2004.

28. CABRAL, João M. Peixoto. *A radioatividade*, op. cit., p. 241.

activity about the documentary, aimed at SE students. We asked them to reflect upon how they would use this audio-visual resource in an activity with their SE students. What kind of questions they would pose to or discuss with them?

3. ANALYSIS OF THE INFORMATION COLLECTED

3.1. Students' answers to the questionnaire

We selected the answers that we considered most relevant to address the questions posed by this study. All the undergraduates' names were changed. The first question was about the language used in the documentary: *Do you consider that the language used in the documentary is suitable for the age group of secondary education students? Justify your answer.* Undergraduate Larissa answered that:

The language used in the documentary, despite the presence of technical terms in some parts, I consider it suitable to use in secondary education, because it's a way to introduce them to terms and words used in science. We must stress that some students have difficulty to differentiate between fiction and documentary, so I suggest that it is made explicit that the cave is real and the documentary is truthful and that the 32,000 years dating is reliable because it could cause disbelief in the students. (Larissa)

In the first part of her answer, Larissa talks about the fact that the documentary language includes technical terms. She stresses the suitability to SE students because it introduces them to scientific language. The second part of her answer, however, alludes to a one-way production of meaning; first, by proposing a strict distinction between what is real and fiction in a documentary film by categorizing it as the truth. The immediate production conditions, that included not only the Herzog's documentary related activities, but also the readings done in the course Physics Teaching Practices II, also included a critical discussion of the concept of documentary, particularly by reading and discussing the already mentioned text by Bruzzo, in which she analyzes the distinction between *reality* and *fiction*, and concludes that: "Without a doubt it is important to do not have any illusion about the veracity of documentaries, of all kinds of movies, but it does not mean, however, that the director is a liar"²⁹.

By taking a position about the *reality* and *fiction* dichotomy in documentaries, we believe that Larissa ends taking a position about science itself; if one considers the documentary a truthful expression of *reality*, the science presented in it should also be considered an expression of reality. According to her, when using this resource with SE students, we should state since the beginning that "the 32,000 years dating is reliable because it could cause disbelief in the students". If we argue for a teaching practice that promotes the discussion of controversies, dislocating the teacher's discourse of authority towards a polemic discourse, in which the student's act of taking a position is crucial, it is exactly the *disbelief*, in the sense of expressing curiosity, that we would seek to promote in physics

29. BRUZZO, Cristina. O documentário em sala de aula, op. cit.

classes in secondary education. Moreover, in the case of the paintings of Chauvet Cave, there still are controversies about its age, with carbon-14 datings being contrasted with datings obtained using the stylistic method, which is based on comparisons between the styles of Chauvet paintings and others already known.

That Larissa points out the necessity of stating that the cave is *real*, the documentary is *truthful* and the 32,000 years dating is *reliable* may be related to her discursive memory of documentary viewer. Many of these audio-visual resources, especially the ones produced in the last decade, make use of special effects and computer generated graphics in order to transmit a sense of “reality” and “truthfulness”. Many of them tend to use various kinds of special effects, enabled by advances in computer graphics, not necessarily associated with a referent in the real world³⁰. This tendency aims to clarify and illustrate abstract scientific theories. In relation to the term “truthfulness” used by Larissa, we emphasize another feature of current documentaries related to narrative mode: the interviews with renowned researchers in the field under discussion. The ways these interviews are made or shown often serve to legitimize the scientific content being presented. In the case of the documentary *Cave of forgotten dreams*, if Herzog were to use this technique, all the researchers interviewed would have to confirm the same dating for the paintings discovered, thus giving the viewer a sensation of the truthfulness of the information presented. That is not the case here, however, since we can perceive that the aesthetic concerns of the director and his care in gathering and presenting different views and opinions prevail over the “purely” scientific elements of the narrative.

We used the second question in our questionnaire to investigate the production of meaning related to the visual resolution of the documentary and to inquire if this is a relevant issue in interpreting the paintings showed. The question was: *Do you consider the fact that the documentary was filmed in high definition important in a classroom context? Justify your answer.* As expected, the answers were similar, but the justifications had their own nuances.

Yes. A documentary with a high quality (of images) makes the student more interested than lower definition documentaries because in the lower definition ones the images are less clear and consequently less capable of retaining the students' attention. (Fernanda)

I consider that high definition images are attractive in any context, a low-resolution image would interfere with perceiving the details of the paintings, for example, the legs of the horses simulating movement. (Larissa)

Yes. I believe that by itself [the high-definition image] engenders a kind of comfort and well-being. Imagine that you are seated in a chair that's already not very comfortable, watching something that maybe doesn't attract your attention, and the video is distorted due to its low quality. Moreover, many scenes are located in a dark environment, so the quality of the video is very important. (Márcio)

30. DIJCK, José Van. *Picturizing science*, op. cit.

Yes, because it transmits a sensation of greater reality, since the documentary is about paintings and images it would be bad if it didn't have enough quality to retain the students' attention. (Breno)

One important point to consider in analyzing the answers for this question is the adherence by all undergraduates to the idea that the quality of the documentary's image resolution is associated to "retaining" the students' attention. Another aspect pointed out by Larissa, is the association between quality of image and comprehension of what is being presented, emphasizing that "a low-resolution image would interfere with perceiving the details of the paintings, for example, the legs of the horses simulating movement." The image mentioned by the undergraduate appears in a scene of the documentary and is shown here in two "versions": high quality and low quality.



Figure 1a: "High quality" or high-resolution image.



Figure 1b: "Low quality" or low-resolution image.

Source: screenshot excerpt from Herzog's documentary in high (1080p) and low (240p) quality, respectively³¹.

We can observe that the high-quality image enables other interpretations of the same referent, by representing another reality. In a classroom context, teacher mediation is important to critically discuss and negotiate meanings. One possible interpretation of Figure 1a involves the idea of movement; however, by framing another field of vision, the same image produces another reading: the idea of escape (Figure 2).



Figure 2: Under an enlarged framing, the image in Figure 1^a transmits the ideas of escape and of representation of reality by Paleolithic man, 32,000 years ago.

Source: screenshot excerpt from Herzog's documentary, in high definition³².

31. Disponível em: <<https://www.youtube.com/watch?v=NfF989-rW04&t=135s>>. Acesso em: 14 jun. 2017.

32. Disponível em: <https://www.google.com.br/search?q=caverna+doss+sonhos+esquecidos&source=lnms&tbn=isch&sa=X&ved=0ahUKewiKo-bGnr7UAhVSlpAKHQIDCaKQ_AUICgD&biw=1280&bih=591#q=chavet+cave&tbn=isch&tbs=isz:lt,ist:sga&imgsrc=fAX09jEc_hBG_M>. Acesso em: 14 jun. 2017.

Figure 2 refers us to other significations, other interpretations, besides the idea of movement, already represented in Figure 1a. In it, we get an impression of escape, as if the animals at the front of the band were running from the ones behind, the lions. The choice of a particular field of vision alters how the image functions in the classroom, stressing the importance of the teacher as a mediator and negotiator of meanings in the classroom³³.

In light of such faith in images, our first task is reversing the process and draw attention to the frame, to the relationship between the photograph and its surroundings, to the fact that the *meaning* is woven from the relationships between the visible and the invisible in each situation.

When talking about how cinema and director, by making a choice that produces the silencing of another, create ideologically the framing of images in movement, Xavier goes on:

The image that I receive is part of a world filtered by a perspective exterior to me, which organizes the appearance of things, establishing a bridge, but also interposing itself between the world and me. It is a perspective prior to mine, whose circumstance does not get confused with mine inside the projection room³⁴.

Figure 2, also in high resolution, has the potential to reveal details and different perspectives of the Chauvet Cave paintings, like the realization that humans in the Paleolithic, 32,000 years ago, were already using the relief of cave walls to represent the impression of depth and movement, in other words, the idea of 3D representation of images. According to Herzog, who is still averse to adopt 3D filming in his movies, allowing this kind of enhanced perception of the paintings was one of the reasons that led him to film the documentary using the 3D technique³⁵.

The third question purpose was to induce the undergraduates to search for MP concepts in the documentary and to engage them in discussions about the development of a learning activity using this resource aimed for a secondary education physics class. The question was: *Dates of events in the past are mentioned in the documentary. a) How do you think scientists know about these dates? b) What Physics has to do with it?*

As expected, the undergraduates' answers to the item *a* mention carbon-14. As to the item *b*, they mention not only carbon-14 but also other MP concepts found in the documentary. Fernanda, for instance, affirms:

Physics, or more specifically, modern physics, relates to it because it studies radioactive decaying. Besides other points in the documentary that also relate to physics, for example: light, *lasers*, etc. (Fernanda)

Márcio historicizes his answer by adding information about the technique and its development:

The carbon-14 dating is based on the half-life of this element, that is, the time in which half of the sample decays, thus emitting radiation. These processes are phenomena studied in physics. The techniques that ascertain the amount of carbon-14 also pertain to the field of physics. (Márcio)

33. XAVIER, Ismail. *O olhar e a cena*, op. cit., p. 32.

34. Idem, p. 35.

35. KLINGER, Barbara. *Cave of forgotten dreams: meditations on 3D*. *Film Quarterly*, Oakland, v. 65, n. 3, p. 38-43, 2012.

The purpose of the third question was to the undergraduates to relate the MP concepts mentioned in the documentary, which, in any way, have contributed to the comprehension of aspects of the paintings or the cave.

After the undergraduates answered the questions proposed by the teacher, we asked them to prepare a set of questions aimed at their future students in a hypothetical learning activity in SE. The only requirement was that the questions had to relate to Herzog's documentary, if possible taking into account the MP concepts presented in it.

3.2. The questions prepared by the undergraduates

We selected below a question proposed by one of the students, which problematizes the perception of images and their possible representations. It is interesting to note the undergraduate's intention of proposing reflections of a multidisciplinary nature, relating physics and culture.

Question 5. In the beginnings of history, man made his drawings on the walls of caves, today in various parts of the city we see drawings like the ones showed in Figure 3, on a wall in the city of Sorocaba, this art is called graffiti. What are the similarities between these two drawings? What necessity led these two individuals to make their drawings? (Larissa)



Figure 3: Left, paintings depicting rhinoceros in Chauvet Cave. Right, graffiti made by Will Graffiti, located in Juscelino Kubitschek Avenue, Sorocaba (SP)

The undergraduate shows a concern to discuss questions that have the potential to produce a dislocation of the *authoritarian discourse* towards a *polemic discourse*, enabling polysemy in SE physics classes. Questions of this kind promote a critical reading of images, static or in movement, by leading SE students to historicize their discourse, as they search for elements, both in immediate and in socio-historical production conditions, to respond to them. This question stresses the presence of discursive memory, since the teacher has neither presented nor discussed issues relating aspects of past and present in his immediate production conditions. We can associate it to a kind of historical repetition, in which, according to Orlandi³⁶, “we have a student that engages in a real work of memory:

he inscribes thus what is said in his discursive knowledge, which enables him to not only just to repeat, but to cause dislocations, drifting effects in what is said”.

3.3. Talking about the documentary

Teacher and undergraduates discussed the documentary in a session of around 50 minutes. Early in the session, when we asked them if they would use the documentary in a class with their future SE students, Breno was the first to respond:

I'd like to use this documentary. But I'd first discuss the subject of carbon-14, then I'd show the documentary without mentioning that it's related to the subject studied to see if they... (Breno)

Would you show the documentary after teaching the subject? (Teacher)

After teaching the subject of carbon-14, even if I were to discuss the subject in depth, but first I would situate them in this kind of subject. (Breno)

In Márcio's opinion, showing the documentary before and discussing the concepts later would be more appropriate. Moreover, he extended the application of the documentary to other possible subjects in the field of MP:

I would make clear in the [expected] outcome not only the relationship with carbon-14 but would... I would ask them to pay attention to possible concepts related to physics. What could they see of physics in the documentary? (Márcio)

Would you present this question before showing the documentary? (Teacher)

Yes. First thing. And then I would discuss the concept they would need. Because in this way... Besides carbon-14 it mentions cold light, laser, so [there are] many concepts to discuss. (Márcio)

In this case, the documentary seems to function as a catalyst to discuss possible topics of physics. Before showing it to the students, Márcio would pose an initial question to help them look for physics related concepts. According to him, it is possible to discuss other topics beyond carbon-14 dating, for example, cold light and laser. He also points out the importance of “looking for the physics” in the documentary, highlighting that this resource may be a means to introduce MP related concepts in SE physics classes.

As we pointed out earlier, one of the uses of documentaries in classroom pointed out by secondary education teachers is to arouse in the students the curiosity and the interest to learn more about the subjects under study. When we asked the undergraduates about this, the response was unanimous:

Do you think that this kind of activity that we did here using documentaries [...] arouse the curiosity to learn more about that subject later on? Let's suppose that you, as a secondary school teacher, go to discuss the subject of radioactive decaying. What do you think is more “effective” to arouse a possible curiosity in the student, a taste for the subject: to approach this subject in depth mathematically or talk about it like we did here? (Teacher)

By doing activities like this one that we did here. The less mathematics the better. (Fernanda)

I agree. (Breno)

Me too. (Márcio)

36. ORLANDI, Eni L. Puccinelli. *Interpretação: autoria, leitura e efeitos do trabalho simbólico*. Petrópolis: Vozes, 1998, p. 14.

It is possible that the undergraduates used the anticipation mechanism here, since the question was rather inducing: they responded what the teacher would like to hear. When asked about why teachers in secondary school do just the opposite, i.e. to favor mathematics over other teaching strategies, they answered:

It's more convenient, it's easier, it was always [done] like this. (Fernanda)

Nobody does this kind of activity like [the one] the teacher did here in undergrad courses. Nobody discusses this in undergrad programs. So the teacher doesn't know what to do in this kind of situation. He only sees calculations and then does the same in secondary education. (Breno)

It's more convenient for him to teach what is already there in the book. (Fernanda)

The undergraduates' opinion agree with some research results in the field of science teaching, by pointing out that despite significant curricular changes that took place in the final semesters of undergraduate programs of teacher training:

teachers' practices are still based, due to the lack of alternative theoretical references, on the training models that they experienced in undergraduate education, and also on the practices that are, in some way, hegemonic in the field. In other words, despite the changes that altered curricular structures, the training models adopted by most teachers continue to be very close to the fragmented model that emphasizes transmission, memory, and content, now considered outdated/inadequate to our time³⁷.

In this sense, we believe that the teacher is the main agent able to contribute to promoting discussions in the classroom, enabling students to practice and express their reasoning and to produce alternative readings of audio-visual narratives. Thus, it is necessary that the teacher understand the modes of production, functioning, and circulation of audio-visual discourse in society³⁸.

4. FINAL CONSIDERATIONS

This study provided us with evidence that documentaries can contribute to decentralize the role of teachers as producers of meanings in the classroom. Since this result agrees with the theoretical perspective adopted, concerning the dislocation of authoritarian discourse towards to a polemic one, we believe that our approach contributes to encouraging future physics teachers to reflect upon their role in class, by asking them to create learning activities for secondary education using documentaries. We believe that this approach helps to promote a more democratic education, in which student and teacher produce knowledge about physics, and not just reproduce the metalanguage proper to this subject, forged in research institutions and universities.

We also identified various concerns with not using the documentary just to *illustrate* or *reinforce* subjects, but also to promote teaching strategies more aligned with models that see the teacher's role as a promoter of reflection. This finding is clear in our analysis of the questions about the documentary proposed by the undergraduates, particularly in the case of Larissa's questions.

37. NARDI, Roberto; CORTELA, Beatriz Saleme Corrêa. *Formação inicial de professores de física em universidades públicas*. São Paulo: Livraria da Física, 2015, p. 36.

38. ORLANDI, Eni L. Puccinelli. *Discurso e texto: formulação e circulação dos sentidos*. 3. ed. Campinas: Pontes, 2008.

We point out, however, the necessity to research further how teachers would use documentaries in their classes after participating in activities like the ones described in this study. Our goal was to investigate potential uses of these resources beyond illustration, motivation, and reinforcement of learned content, so we adopted a perspective of bringing together science and art, as we see in the documentary. We did not follow the future teachers interviewed in this study in their professional activities, however, in order to investigate how significant this experience was to them and, thus, to their students.

BIBLIOGRAPHICAL REFERENCES

ALMEIDA, Maria José Pereira Monteiro de. Discurso pedagógico e formação de professores das ciências da natureza: foco no professor de física. **Alexandria**, Florianópolis, v. 5, n. 2, p. 29-41, sept. 2012. Available at: <<https://periodicos.ufsc.br/index.php/alexandria/article/viewFile/37712/28886>>. Accessed on June 13, 2017.

BARBOSA, Leila Cristina Aoyama; BAZZO, Walter Antonio. O uso de documentários para o debate ciência-tecnologia-sociedade (CTS) em sala de aula. **Revista Ensaio**, Rio de Janeiro, v. 15, n. 3, p. 149-161, 2013. Available at: <<http://www.scielo.br/pdf/epec/v15n3/1983-2117-epec-15-03-00149.pdf>>. Accessed on June 13, 2017.

BRUZZO, Cristina. O documentário em sala de aula. **Ciência & Ensino**, v. 4, p. 23-25, 1998. Available at: <<http://prc.ifsp.edu.br:8081/ojs/index.php/cienciaeensino/article/view/32/39>>. Accessed on April 24, 2017.

CABRAL, João M. Peixoto. **A radioatividade**: contributos para a história da arte. Lisboa: IST, 2011. p. 312.

COSTA, Rodrigo Ronelli D.; NASCIMENTO, Robson S.; GERMANO, Marcelo Gomes. Salvador Dalí e a mecânica quântica. **Física na Escola**, v. 8, n. 2, p. 23-26, 2007. Available at: <<http://www.sbfisica.org.br/fne/Vol8/Num2/v08n02a06.pdf>>. Accessed on: 24 abr. 2017.

DIJCK, José Van. Picturizing science: the science documentary as multimedia spectacle. **International Journal of Cultural Studies**, v. 9, n. 1, p. 5-24, 2006. Available at: <<http://journals.sagepub.com/toc/icsa/9/1>>. Accessed on June 14, 2017.

FARIAS, Robson Fernandes. A química do tempo: carbono-14. **Química Nova na Escola**, n. 16, p. 6-8, nov. 2002. Available at: <http://qnesc.sbq.org.br/online/qnesc16/v16_A03.pdf>. Accessed on April 24, 2017.

GUERRA, Andreia; MORAIS, Angelita. História e a filosofia da ciência: caminhos para a inserção de temas física moderna no estudo de energia na primeira série do ensino médio. **Revista Brasileira de Ensino de Física**,

v. 35, n. 1, p. 1502-1511, 2013. Available at: <<http://www.scielo.br/pdf/rbef/v35n1/v35n1a18.pdf>> Accessed on April 24, 2017.

HERZOG, Werner. *Cave of forgotten dreams*. Director: Werner Herzog. Screenplay: Werner Herzog. Narrator: Werner Herzog. EUA: History Films, 2010. (90 min). Available at: <<https://www.youtube.com/watch?v=IzcregYsle4&t=14s>>. Accessed on June 4, 2017.

KLINGER, Barbara. Cave of forgotten dreams: meditations on 3D. **Film Quarterly**, Oakland, v. 65, n. 3, p. 38-43, 2012.

LEÃO, Rita de Cássia da Silva. **Werner Herzog em busca da compreensão humana**. Doctoral dissertation on Social Sciences. Anthropology Department, Pontifícia Universidade Católica de São Paulo, São Paulo, 2015. Available at: <<https://sapientia.pucsp.br/ande/handle/3655>>. Accessed on September 16, 2017.

LEÓN, Bienvenido. **Science on Television: the narrative of scientific documentary**. Bedfordshire: Pantaneto, 2007.

LOBATO, Teresa; GRECA, Ileana María. Análise da inserção de conteúdos de teoria quântica nos currículos de física do ensino médio. **Ciência & Educação**, Bauru, v. 11, n. 1, p. 119-132, 2005. Available at: <<http://www.scielo.br/pdf/ciedu/v11n1/10.pdf>>. Accessed on April 24, 2017.

MARTINS, André Ferrer P. (Org.). **Física ainda é cultura?**. São Paulo: Livraria da Física, 2009.

MORIN, Edgar. **Ciência com consciência**. Rio de Janeiro: Bertrand Brasil, 2010.

NARDI, Roberto; CORTELA, Beatriz Salemme Corrêa. **Formação inicial de professores de física em universidades públicas**. São Paulo: Livraria da Física, 2015.

ORLANDI, Eni de Lourdes Puccinelli. **A linguagem e seu funcionamento: as formas do discurso**. São Paulo: Pontes, 2001.

_____. **Análise de discurso: princípios & procedimentos**. Campinas: Pontes, 2010.

_____. **Discurso e texto: formulação e circulação dos sentidos**. 3. ed. Campinas: Pontes, 2008.

_____. **Interpretação: autoria, leitura e efeitos do trabalho simbólico**. Petrópolis: Vozes, 1998.

RAMOS, Mariana Brasil; SILVA, Henrique César. Educação em ciência e em audiovisual: olhares para a formação de leitores de ciências. **Cadernos CEDES**, Campinas, v. 34, n. 92, p. 51-67, jan./abr. 2014. Available at: <<http://www.scielo.br/pdf/ccedes/v34n92/a04v34n92.pdf>>. Accessed on April 24, 2017.

REID, Grace. The television drama-documentary (dramadoc) as a form of science communication. **Public Understanding of Science**, v. 21, n. 8, p. 984 – 1001, nov. 2012.

REZENDE JUNIOR, Mikael Frank; CRUZ, Frederico Firmo de Souza. Física moderna e contemporânea na formação de licenciandos em física: necessidades, conflitos e perspectivas. **Ciência & Educação**, Bauru, v. 15, n. 2, p. 305-321, 2009. Available at: <<http://www.scielo.br/pdf/ciedu/v15n2/a05v15n2.pdf>> Accessed on April 24, 2017.

VALLADAS, Hélène; CLOTTE, Jean; GENESTE, Jean-Michel. A caverna onde a arte nasceu. **Scientific American Brasil**, São Paulo, n. 31, 2004.

XAVIER, Ismail. **O olhar e a cena: melodrama, Hollywood, Cinema Novo**, Nelson Rodrigues. São Paulo: Cosac & Naify, 2003.

ZANETIC, João. Física e arte: uma ponte entre duas culturas. **Pro-Posições**, Campinas, v. 17, n. 1, p. 39-57, 2006. Available at: <<http://periodicos.sbu.unicamp.br/ojs/index.php/proposic/article/view/8643654/11171>>. Accessed on April 24, 2017.

_____. **Física também é cultura**. Doctoral dissertation. Faculdade de Educação da Universidade de São Paulo, São Paulo, 1989.