USE OF VIDEOS IN SCIENCE DISSEMINATION ACTIVITIES ABOUT BLACK HOLES AND GRAVITATIONAL WAVES

USO DE VÍDEOS EM ATIVIDADES DE DIVULGAÇÃO CIENTÍFICA SOBRE BURACOS NEGROS E ONDAS GRAVITACIONAIS

USO DE VIDEOS EN ACTIVIDADES DE DIFUSIÓN CIENTÍFICA SOBRE AGUJEROS NEGROS Y ONDAS GRAVITACIONALES

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ABSTRACT: This research analyzed the didactic use of audiovisual presentations of scientific dissemination for the teaching of astronomy themes, such as black holes and gravitational waves, in which short videos and scenes from films and documentaries were used. The investigation carried out was characterized as exploratory and qualitative, through an interrogative and reflective process, seeking to understand the facts observed to point to new possibilities for scientific education. The scientific dissemination actions carried out indicated a great interest by students in astronomy and astrophysics themes.

KEYWORDS: Dissemination of science. Astronomy. Audiovisual resource. History of science.

RESUMO: *Esta pesquisa analisou a utilização didática de apresentações audiovisuais de divulgação científica para o ensino de temas de astronomia, tais como buracos negros e ondas gravitacionais, nas quais foram usados vídeos de curta duração e cenas de filmes e de documentários. A investigação realizada caracterizou-se como exploratória e qualitativa, mediante um processo interrogativo e reflexivo, buscando compreender os fatos observados com o intuito de apontar para novas possibilidades para a educação científica. As ações de divulgação científica realizadas indicaram um grande interesse dos alunos por temas de astronomia e astrofísica.*

PALAVRAS-CHAVE: *Divulgação da ciência. Astronomia. Recurso audiovisual. História da ciência.*

RESUMEN: *Esta investigación analizó el uso didáctico de presentaciones audiovisuales de divulgación científica para la enseñanza de temas de astronomía, como agujeros negros y ondas gravitacionales, en las que se utilizaron videos cortos y escenas de películas y documentales. La investigación realizada se caracterizó por ser exploratoria y cualitativa, a través de un proceso interrogativo y reflexivo, buscando comprender los hechos observados con el fin de señalar nuevas posibilidades para la educación científica. Las acciones de divulgación científica realizadas indicaron un gran interés de los estudiantes por temas de astronomia y astrofísica.*

PALABRAS CLAVE: *Difusión de la ciencia. Astronomía. Recurso audiovisual. Historia de la ciencia.*

Introduction

Since ancient times, humanity has been observing and studying the stars and other objects in the sky; phenomenology of what was observed, most of the time. The study of astronomy allows the human being to better understand his spatial position and understand some of the phenomena observable in nature: to understand the phenomena present on our planet, in some cases, it is vital to "look" beyond the Earth's atmosphere, as man has done since time immemorial. The understanding about the sky and the universe was a concern that permeated several cultures, from the simplest to the most sophisticated in technological terms (FERREIRA; MEGLHIORATTI, 2008).

In Egypt and Mesopotamia, approximately in the third millennium BC, having as its starting point the imperatives and needs of everyday life, associated with the development of agricultural production, the seasons (knowledge about what time to sow) and the exchange of products (need for counting and quantification), astronomy and mathematics arose, the first two sciences (ROSMORDUC, 1983).

In the 17th century, Isaac Newton (1643-1727) mathematically structured the idea of the existence of a force of action at a distance to explain the gravitational pull between any two objects with mass, that is, also between the celestial bodies. Newton began to observe the tidal changes and, as many attentive fishermen had already noticed, noticed there was a coincidence between the phases of the Moon and the high and low tides. Thus, after years of studies and observations, he came to the famous expression that explains the behavior of gravitational force, concluding that all stars were subject to this force and that mass attracts mass. The earth's gravity weakens in a way inversely proportional to the square of the distance: thus, it is divided by four when we double the distance. The law of gravitation is very important on cosmological scales, to explain the functioning of the Universe (FEYNMAN, 2012).

Newton unified two areas that, until then, were seen separately (VERDET, 1991): the study of the fall of bodies, whose laws were previously given by Galileo Galilei (1564-1642), and the study of the revolution of the Moon around the Earth, which followed the empirical rules previously developed by Johannes Kepler (1571-1630).

Further historically, in the 19th century, the most abstract idea of the existence of fields that allow – mediating – the action at a distance of a force was consolidated through the work of Michael Faraday (REIS, 2006).

Modern physics had its prologue in the study of the heavens: its origins are situated in

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the study of astronomical problems and this bond was maintained throughout the history of science. Throughout this process, there were important transformations in the predominant worldview, in particular the abandonment of the conception of the cosmos as a closed and hierarchically ordered unit, in which heaven and earth were subject to different laws, which was replaced by the conception of an open universe, indefinitely extensive and united by the same fundamental laws that govern all its constituent parts, which implied the Newtonian fusion of celestial physics with terrestrial physics (KOYRÉ, 1943).

Black holes and gravitational waves

In 1783, in the context of Newtonian mechanics, the English scientist John Michell (1724-1793) proposed the concept of "dark star", a star with sufficiently high density that not even light could escape its gravitational pull (GRAHAM, 2017). Later, general relativity, from the work of physicist Albert Einstein (1879-1955), developed during the second decade of the 20th century, using a sophisticated mathematical approach to study the effects of gravitational action: the tensorial equations. The non-linearity of problems and the number of equations that represent a single phenomenon can be overcome today thanks to computational development that facilitated the understanding of various phenomena (HORVATH, 2007). Some physicists and mathematicians have dedicated themselves to proposing solutions to problems arising from general relativity, such as Karl Schwarzschild's (1873-1916) metrics, which describe an external gravitational field to certain bodies with spherical symmetry, without rotation. With the new technologies applied to the field of cosmology and astronomy, especially in the field of observation, the theoretical predictions were acquiring body and confirming themselves.

One of the universe models resulting from the theory of relativity was one in which the space-time tessitura could be distorted by violent events associated with the shock of bodies with an abundance of matter: space-time, as a structure, would feel the effects of these shocks in the form of waves. Gravitational waves are transverse waves that move at the speed of light. They are generated by cosmic events of unimaginable proportions involving stars with gigantic masses, such as the fusion of black holes or binary neutron star systems. Although gravitational radiation presents many experimental difficulties to be detected, its main advantage is that it can fully diagnose the universe because all the matter contained in the universe interacts with gravitational waves (ASSIS, 2016).

On September 14, 2015, LIGO scientists, "*Laser Interferometer Gravitational-Wave*

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Observatory" or "Gravitational Wave Observatory by Laser Interferometer"[1], were able to observe gravitational waves resulting from the shock between two supermassive black holes, which were located about 1.2 billion light-years away from Earth. Laser interferometry is an experimental method to determine distances very precisely, using the known phenomenon of wave interference of any type (sound, light or gravitational), by a structure in the form of the letter L, with two arms forming a right angle. It was the first time gravitational waves formed by the coalescence of two black holes were detected directly. The orbital decay of binary systems of black holes causes the loss of energy of the system that propagates in the form of gravitational waves. The GW150914 event was revealed by the structure of the LIGO laboratory in Hanford and Livingston in the United States (ABBOTT *et al.*, 2016). These gravitational waves were formed by the coalescence of two black holes, whose masses (worth 36 and 29 solar masses) added up were about 65 solar masses; in this case about 3 solar masses were irradiated in the form of gravitational waves (MOFFAT, 2016). A second observation of gravitational waves, also made by LIGO, took place on December 26, 2015; this event, called GW151226, also occurred due to the coalescence of a binary system formed by two black holes (BASSALO; CATTANI, 2016). The detection of these tiny tremors in space-time resulting from black holes colliding, LIGO opened a new "window" of observation of the universe, in a sense, similar to what Galileo did in 1609 when he first pointed a telescope at the sky (WOLCHOVER, 2016).

In January 2017, a new detection of gravitational waves was made by LIGO, the event GW170104 (ABBOTT *et al.*, 2017). In this detection the combined mass of the two black holes that coalesced was about 50 solar masses, with the event having occurred about 3 billion light-years away from Earth. An existing problem was the determination of the specific region of space from which these gravitational waves come from: this can only be solved by triangulation, which will occur in the near future with the use of the VIRGO observatory (in Italy), which will be a third observation point along with the two LIGO facilities, existing in the USA, in Hanford and Livingston. There are interesting mathematical developments on this issue that can be worked on in scientific education activities: for example, analogies with the determination of a person's position through GPS (which requires three references) and with the determination of the epicenter of an earthquake or tsunami, which is a gigantic maritime wave that holds certain similarities with gravitational waves, in a didactic approach. The detection of gravitational

[1] Available: https://www.ligo.org. Access: 10 Feb. 2021.

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waves had the additional role of confirming the existence of black holes themselves, a class of objects originating from supermassive stars.

On January 13, 1916, an article prepared by the German physicist and astronomer Karl Schwarzschild (1873-1916) was published in the Papers of the Royal Academy of Sciences of Prussia, containing a result obtained on the gravitational field according to general relativity. This first 1916 work by Schwarzschild is available on the Internet in his Translation into English, with the title "*On the gravitational field of a mass point according to Einstein's theory" or, in* Portuguese, "On the gravitational field of a point with a punctiform mass according to Einstein's Theory" (SCHWARZSCHILD, 1916a). The result of this research described a simple type of a new class of objects, called black holes. Schwarzschild in 1913 was elected a member of the Berlin Academy of Sciences, in 1914 he joined the Germanic army and fought for his country in World War I against Soviet soldiers, directing his efforts to perform ballistic and meteorological calculations.

According to the Theory of General Relativity, gravitational interaction is not mediated by potentials, but by the geometric properties of space-time, a concept that was introduced in 1908 by mathematician Hermann Minkowski (1864-1909). The interpretation of the effects of space-time curvature was only consolidated when a second Schwarzschild article was published, sent on February 24, 2016, which took into account a spherical and homogeneous distribution of matter. This second work of 1916 by Schwarzschild is available on the internet in its original German version with the title "*Über das gravitationsfeld einer kugel aus inkompressibler flüssigkeit nach der Einsteinschen theorie*" or, in English, "On the gravitational field of a sphere made with an incompressible liquid according to Einstein's Theory" (SCHWARZSCHILD, 1916b). It is in this second article that the amount r_s, the so-called Schwarzschild radius, first appears. From the equality between the speed of light and the speed that an object needs to have to escape the gravitational pull force of an M mass body, it is possible to obtain that $r_s=2GM/c^2$, being c the speed of light in the vacuum, M the mass of the object and G the universal gravitation constant (SANTI, 2018). This mathematical formula is associated with a certain radius of curvature of the geometry of space time, caused by a massive body, in which the escape velocity is the same as that of light. That is, this formula describes a "place" near a body with a large mass from which, every object that falls on it (and is within this radius), remains eternally trapped inside this body and even if it manages to acquire the speed of light (the highest speed allowed by the Theory of Relativity), it cannot get out of it, because the exhaust speed is greater than the speed of light! This is the so-called Event

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Horizon, a kind of surface that circulates a black hole: the science that explains through its general laws what happens in the universe, from this surface, towards the singularity, which is the center of the black hole, loses validity as to its principles and its laws.

Interest in black holes was reborn in the 1950s from the work of David Finkelstein (1929-2016), who interpreted the spherical surface with the Schwarzschild ray as a one-sided membrane shape (FINKELSTEIN, 1958) between two regions, and the outer region was totally disconnected from the inner region, with no possibility of communicating the interior of the black hole with its exterior (SAA, 2017): influences can cross this membrane, but only in one direction. This work was fundamental to accept the physical existence of the concept of event horizon and, consequently, black holes, encouraging the emergence of the vibrant research area today that is the astrophysics of black holes.

Schwarzschild's two articles on the Theory of Relativity published in early 1916 were written in mid-1915, when the author was serving in the German army during World War I (1914-1918). Shortly after the publication of these two articles, on May 11, 1916, Karl Schwarzschild would later die of an autoimmune and painful skin disease, pemphigus.

Finally, it is important to remember the work of Stephen Hawking who in 1973 discovered that, thanks to a combination of quantum and gravitational effects, black holes were not completely black and let out radiation (Hawking's radiation), due to the fact that at the edge of the event horizon, quantum effects allowed pairs of particles and antiparticles to emerge from nothing, and due to the gravitational effects, one of the partners of each of these pairs disappeared into the black hole, while the other escaped towards outer space (PANEK, 2014).

Astronomy teaching

Many research papers have highlighted that it is important to teach physics in a multidisciplinary manner, articulating at different levels concepts of this science with other elements of human culture (PORTO; PORTO, 2008; OLIVEIRA, 2020). Astronomy is a science that by nature presents itself with several interdisciplinary relationships with other areas of knowledge, just remembering for these terms such as astrophysics, astrochemistry, astrobiology, astroinformatics and astro-statistics. Concepts of astronomy are part of the program of science or geography in elementary school, besides being also addressed in the disciplines of physics and chemistry in high school (BRETONES, 2006; LEITE, 2006; SOLBES; PALOMAR, 2013; VOELZKE; MACÊDO, 2020).

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There are a number of works that point to several potentialities that the teaching of astronomy offers for the educational process and that are often wasted. Several studies also indicate that astronomy has an immense capacity to captivate young people to science. Therefore, themes of astronomy, astrophysics and cosmology can constitute, if well worked, strong interdisciplinary resources, taking into perspective the fact that encompass knowledge of various areas of knowledge.

The breadth and diversity of knowledge produced by human beings has created what is called human culture (TYLOR, 2014), which includes the arts, laws, customs, habits, skills, beliefs and also sciences. The concept of human culture is intrinsically related to the concept of civilization: cultural evolution materialized in the civilizing process and generated the cultural diversity existing in humanity, in a sense, a counter to the biological unity of the human species (LARAIA, 2009). However, generally, when it comes to culture, physics is rarely – let alone astronomy – remembered (ZANETIC, 2005). However, physical concepts are creations of the human mind – such as a book or a symphony – not being determined solely by the outside world (EINSTEIN; INFELD, 2008). The academic and university world is divided between two cultures: there are the humanities and the arts on one side (traditionally associated with erudite culture) and there are natural sciences and technologies on the other hand (SNOW, 2015). The reading of classical literary texts often leads the reader to a state of mental involvement, for the space allowed for the beautiful, the playful, the fantasies and the emotions; similarly, this is possible with the reading of a good book of scientific dissemination.

Today's society has in the intensive use of image and sound one of its main characteristics. In particular, science fiction can become a didactic tool for stimulating imagination on issues originated in science and in people's sociocultural relationship with it (PIASSI; PIETROCOLA, 2009). Science in general – and physics and astronomy in particular – must be part of the cultural formation of the contemporary citizen, regardless of the differences of individual interests that exist (ZANETIC, 2006): this is the baggage of knowledge that we have, because we are part of the whole that we call humanity. Presenting the scientific knowledge accumulated by humanity to basic education students is always a challenge.

The audiovisual language underlying the new Information and Communication Technologies (ICT) permeates much of the relationships between people in the modern world, both during leisure time and during working hours: that is why there is great educational potential in the use of audiovisual resources, given their participation in everyday life

(ATANAZIO; LEITE, 2018).

The partnership between science teaching and the study of how to use videos as a teaching resource has been consolidating for a long time. Audiovisual resources have been used to illustrate, present and discuss scientific ideas, principles and concepts in order to motivate, sensitize or problematize. The videos, however, need to be thought of from the point of view of the formation of science readers, not only in the sense of readers of verbal and written texts, but also of readers of moving images and sounds in videos (RAMOS; SILVA, 2014). In this sense, it is essential to educate young people to the domain of symbolic reading (ALMEIDA, 2004), that is, for reading television, cinema, photography, music, images and sounds.

Scientific dissemination activities carried out

This exploratory research investigated how educational interventions, using short-lived videos and cut-out excerpts from films or scientific documentaries, can effectively contribute to the creation of new teaching dynamics and to the learning of important scientific concepts. The internet – and its video storage sites such as YouTube with almost unlimited capacity – is a "barn" for discovering astronomy-specific audiovisual materials, which by their originality can be powerful and useful educational tools.

Due to the type of language and the images and sounds presented, many scientific videos on topics related to astronomy can in fact combat the indisposition among many students – in some cases, the feeling is defined as being "hate", in the words of some students – with regard to the discipline of physics in high school (MOREIRA, 2018). It is paradoxical that astronomy produces a true fascination in a considerable portion of students (and citizens in general) and at the same time physics – which in its genesis is intensely related to astronomy – produce so much aversion among high school students: it is, in a sense, a mixture of love and hatred, focused not on the same focus, obviously.

The history of science was an important part of this research, as it can make sense of science teaching for children, adolescents and young people, in particular, with an educational work that seeks to address topics in the history of astronomy. The use of the history of science in education can "humanize" the contents of natural sciences taught, placing the student in a context that reveals the complexity of the historical evolution of scientific theories and the discoveries that happened, allowing a better understanding of the generally non-linear paths of the process of construction of human knowledge (EINSTEIN; INFELD, 2008; WHITE, 2003).

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To work with the history of science in the classroom is to give due importance to the cultural value that science has in our society; it also allows to improve the understanding of scientific methodologies in various areas, thus emphasizing the diverse character of knowledge produced by human societies (CHASSOT, 2014; PIASSI; PIETROCOLA, 2009; STANNARD, 2011).

During this research, educational activities of scientific dissemination were structured and carried out, with the use of audiovisual materials, in particular videos. The results of these activities were evaluated in view of their impacts and by attentive observation about how they happened and the possibilities of dialogue created with the students involved. Thus, a dozen audiovisual presentations of scientific dissemination on gravitational waves and their relationships with black holes were held for different types of publics in 2017 and 2018. These activities took place in public schools in the north coast region of São Paulo and in other spaces, including within the Caraguatatuba campus of the Federal Institute of São Paulo (IFSP-Caraguatatuba), usually for students from educational institutions who were visiting this institution.

The actions of dissemination of science carried out were based on excerpts from scientific documentaries and on some scenes of science fiction films that were available on video storage platforms such as *YouTube*. In addition to this, other sources of audiovisual resources were used, such as ted *talks* from conferences made available on the <https://www.ted.com/> website, videos that are also available on *YouTube* channels, such as the "NASA"[2] channel, and videos produced by astronauts from the *International Space Station* (ISS).

The material produced was structured in the form of a *PowerPoint* file with short videos associated with some specific slides. The lecture or presentation elaborated was aimed at studying the characteristics of "Gravitational Waves" from the perspective of the history of science and technology and, in its full version, was thought to last 60 minutes.

There are still few existing bibliographic references on the treatment and manipulation of film and documentary scenes for educational purposes, in particular for scientific dissemination (BERK; ROCHA, 2019), and only a few authors dialogue with questions about criteria for the selection of videos or film nominations that can be used for educational purposes in certain types of situations (NAPOLITANO, 2013). Thus, for the structuring of the presentation of scientific dissemination on gravitational waves, videos and excerpts of films and documentaries were selected, taking as reference their relevance in relation to the main

[2] Available: https://www.youtube.com/user/NASAtelevision. Access: 10 Feb. 2021.

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contents that were intended to be illustrated, as well as to the scientific concepts treated during the activity.

For this, it was necessary to investigate and know several films, documentaries and videos, many of which did not enter the presentation, in order to be able to select those who had a greater affinity with the theme in focus and whose scenes dialogued better with the concepts addressed in the lecture, in order to provoke reflection and stimulate the imagination of students.

With regard to the use of audiovisual resources, it was necessary to plan the activity completely, taking into account both the representations that students could structure from the daily situations experienced by them, as well as the incentive to critical sense and the habit of observing problems and phenomena in a deeper way. This guidance was important so that students did not treat the display of the videos as a moment of entertainment only, not taking advantage of them for learning scientific content. An active attitude of students was encouraged in the selection and choice of videos they watch on the internet on a daily life, for school research or for entertainment, as protagonists of their own learning – and not as mere consumers of videographic materials – working conceptual and procedural contents that are important for the cognitive formation of citizens (NOGUEIRA; GONÇALVES, 2017).

In spontaneous browsing that students (in fact, all people) make over the internet and on sites such as *YouTube*, the suggestions offered to users, indicating associated content, are produced by an artificial intelligence algorithm whose main focus is the number of views and not the scientific correction of the material displayed or the academic training of the "content producers" for the internet. This makes it even more important that educational activities are strongly focused on the task of empowering students so that they can surf the internet with discernment, responsibility and autonomy.

The choice of the videos presented also took into account the objective of valuing students as being the protagonists of their own learning process. The scenes extracted from science fiction films sought to go beyond the methodology of error checking (PIASSI; PIETROCOLA, 2009). There were several factors analyzed in the cinematographic works of science fiction that were considered to have excerpts included during the presentation: the phenomena that are presented in the films; the scientific concepts that permeate the narratives; scientific accuracy in the scenes present; the moments when scientific principles are contextualized from real-world situations.

Students were asked questions about the nature of the force of gravity, about the

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constitution of celestial objects, and the form of "birth" of stars. A question that particularly attracted the students' attention referred to the so-called hypothetical process called "spaghettiification", which refers to a mental experiment in which a person falls into a black hole, with the axis of that person aligned with the radial direction: in this case, if the person's feet are closer to the center of the black hole than the head, the gravitational pull on the feet will be greater than the gravitational pull on the head. At this moment, in the presentations often performed, the reaction was initially silent, but then questions arose on the part of the students about whether it was possible for a person to stay alive when falling into a black hole and about whether there would be any way for the person to later get out of the black hole. It was observed, during the research carried out, that the use of hypothetical examples of this type aroused the curiosity of the students, who began to associate a concrete situation with a very abstract concept, such as that of a black hole.

Basically, three elements were investigated in the analyzed films: linguistic elements, related to the use of language and the accuracy regarding the terminology used to refer to certain physical phenomena; "objects" elements, which refer to artifacts and other noun elements that appear; phenomenological elements, which refer to the phenomena that were discussed and brought on the scene.

Table 1 – Videos available on the internet used in the presentation

Type of material	Title	How it was used
Internet video	Astronaut shows how amazing it is to twist a wet cloth in space (<https://www.youtube.com/watch?v=OmVAUHSoU-o&t=72s>)	To explain how gravity acts on an astronaut orbiting around the Earth and to explain the concept of weightlessness.
Internet Video	Gravity – Quer que desenhe (<https://www.youtube.com/watch?v=6DFYKiXSLF Y>)	To explain the law of gravity from two points of view, Newtonian and Einsteinian.
Internet Video	Gravitational Waves - Nerdologia (<https://www.youtube.com/watch?v=z71O5cHTOvM&t=30s>)	To explain the experiment of the Laboratory of Gravitational Waves with Laser Interferometry (LIGO) in the United States.

Source: elaborated by the authors (2021)

Documentaries from different sources such as the BBC (British public television channel), PBS (US public television channel) and some pay TV channels such as *Discovery Channel*, *National Geographic* (NatGeo) and *History Channel*, all of which are producers of

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documentaries on the dissemination of knowledge related to physics and astronomy, were investigated and analyzed. Andin some cases, audiovisual materials of excellent quality and that can be useful in lectures, workshops and educational presentations. Other search sources were videos that are available on the internet on *YouTube channels* such as the channels "Nerdologia"[3] and the "Um sábado qualquer" / "Quer que desenhe"[4].

Scientific dissemination within contemporary society is increasingly important, since it is the way society perceives scientific activity and understands its results (MASSARANI; ALVES, 2019). Scientific dissemination – the popularization of science – serves as a bridge between science and the lay public, which, often, however much it uses science and technology in its day-to-day life, does not note their importance for the economic, social and educational development of the collective (CHASSOT, 2003; ROSA, 2012).

One of the factors that influences this situation is the fact that science is increasingly complex and is increasingly departed from citizens. In addition, there is an inability – or lack of willingness – on the part of many scientists to disseminate their research and their studies to the public: either they do not disclose their work or, when they disclose, in various ways, there are difficulties in making the message – that is, the content of their work – understandable to a large part of lay citizens (TORRESI; PARDINI; FERREIRA, 2012). Being understood by people is fundamental to researchers and should actually be one of their elementary obligations. Every scientist should make a commitment to society in favor of the circulation of ideas and the results of his research (CANDOTTI, 2002), because in the vast majority of cases, it is the society that is financing the work of scientists.

Within schools, the use of texts of scientific dissemination has been disseminated as a common practice by some teachers (SILVA, 2006). A video or a scientific documentary is also a "text", composed of moving images and sounds, which can collaborate to bring the student closer to the scientific concepts that are objects of themes worked in the classroom.

The school must train the citizen trained to live in the contemporary world in order to have the basic and necessary understandings regarding science, its results and methods, and the risks and interests involved in its processes and applications (MOREIRA, 2006). This is one of the reasons for inserting science and technology history topics into teaching and there are a lot of short videos and longer-length documentaries available on the internet that can be very

[3] Available: https://www.youtube.com/user/nerdologia. Access: 10 Feb. 2021.
[4] Available: https://www.youtube.com/channel/UCeXoFprcU1KmMiGu1gREsFw. Access: 10 Feb. 2021.

helpful in accomplishing this task.

Final considerations

The audiovisual language of the new Information and Communication Technologies is increasingly present in people's lives, both in their leisure hours and in the hours worked. Therefore, the educational potential of audiovisual is immense, given its participation in everyday life. In this exploratory research, it was investigated how educational interventions from the use of short videos and cut-out excerpts from films or scientific documentaries can contribute to the creation of new dynamics of learning and teaching. These were strategies that proved to be efficient and viable for the public of the schools that were visited and of the IFSP-Caraguatatuba itself. It is important that further research with this profile be conducted with other audiences, in other contexts and working other content.

What can educators benefit from the new technologies associated with the use of audiovisual resources? What new knowledge and skills will teacher training courses have to develop in their students so that they can make good use of these technologies with regard to the teaching-learning process? These are questions that do not exactly have conclusive, closed and definitive answers, but which have great potential to motivate new research that may contribute to improving the quality of education.

Finally, this research allowed a recognition of the great importance of educational work with astronomy themes among students with different levels of schooling. The interdisciplinary relationships established between astronomy and school scientific disciplines, in particular with physics, enable a very diverse range of approaches that can help overcome learning difficulties. In addition, there is great potential in educational work integrating astronomy with the history of science.

In particular, black holes proved to be a subject that provokes the fascination on the part of many of the young people who participated in the scientific dissemination activities that were promoted, perhaps by the peculiar characteristics of these celestial bodies. The recent detection of gravitational waves – which first occurred in 2015 – for the prominence it has had and continues to have and the way they are produced also helps to put the concept of black hole on the agenda in the media and social networks, which contributes to intensify the public's curiosity about this subject and that can serve as motivation in educational activities and scientific dissemination.

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