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The Use of Analogies in Science Communication: Effectiveness of an Activity in Initial Primary Science Teacher Education

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Abstract

This article presents a study focused on analysing the effectiveness of an activity about the use of analogies in science communication. The activity consisted of reading two science articles published in a prestigious digital newspaper about the first image of a black hole. The purpose was (*i*) to identify and analyse the analogies used in the news articles and (*ii*) to assess the advantages and possible limitations of their use in communicating scientific ideas. The activity was performed with prospective primary education teachers (PPTs) who were receiving instruction in science teaching. Their responses were analysed descriptively with a rubric developed in accordance with methods of qualitative content analysis. The results indicate that the PPTs achieved a moderate progression in their conceptions of the use of analogies in science communication and, overall, it can be said that the activity had a positive educative effect. Finally, a discussion of the implications and limitations of the study for PPTs' training in the use of analogies is presented.

Keywords Analogy · Digital press · Prospective primary teachers · Science communication · Science teaching

Introduction

Today's society demands that citizens have a scientific literacy that allows them to be informed of science's advances, assess their socio-economic and environmental repercussions and critically form opinions about them so as to make responsible decisions (Hazelkorn et al., 2015; Siarova, Sternadel, & Szönyi, 2019). For the vast majority of the population, the main source of information about the development of contemporary

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science is that offered by the media (Jarman & McClune, 2007), especially the science sections usually included in prestigious newspapers (Miller, 2004). Therefore, reading and analysing science news published in the media, such as the digital press, should be an essential and routine activity within basic science education (García-Carmona, 2014; Höttecke & Allchin, 2020). This is clearly suggested, for example, in the Spanish science curriculum for lower secondary education (12 – 16 years) when it states that pupils must 'interpret information about scientific issues which appears in publications and the media' (Ministry of Education, 2015, p. 258). The recommendation is to start with the development of this competency during the primary education stage (6 – 12 years) (Weissmann, 2014), something that the official science curriculum of this stage makes equally explicit through the following learning standard (Ministry of Education, 2014): '[The pupils] develop appropriate strategies to access information from scientific texts' (p. 19367).

Logically, science news items published in the digital press are aimed at a diverse public, so an attempt is made to use language that is understandable for everyone. This often involves the use of linguistic resources such as metaphors[1] and analogies to make the ideas presented more 'accessible' (Taylor & Dewsbury, 2018), even at the risk of compromising the scientific rigour of the message. Consequently, critical analysis of this should also be part of the scientific literacy process that is promoted in the classroom.

The use of analogies is something inherent in the development of science (Brown & Salter, 2010), and for decades has been promoted as an essential resource in its teaching and learning (Duit, 1991). In the literature, it is possible to find studies on the effectiveness of the use of analogies with primary (e.g. Haglund, Jeppsson, & Andersson, 2012) and secondary school pupils (e.g. Aragón, Oliva, & Navarrete, 2014), and university undergraduates (e.g. Orgill & Bodner, 2004), as well as in the training of secondary education science teachers (e.g. Treagust, Harrison, & Venville, 1998). All highlight the educative benefits of the use of analogies for learning science.

However, studies carried out with prospective primary education teachers (e.g. Emig, McDonald, Zembal-Saul, & Strauss, 2014) are much scarcer. Therefore, the purpose of this study was to implement and evaluate the effectiveness of an activity aimed at detecting, analysing and reflecting on the use of analogies in two science news published in a digital newspaper, in the training of prospective primary education teachers (hereafter, PPTs).

The Role of Analogies in Science and Its Teaching

The history of science shows that the use of analogies (or analogue models) has always been an essential resource for communicating scientific ideas and promoting their understanding (Acevedo, 2004). The assimilation of Thomson's model as a plum pudding, Maxwell's demon proposal to illustrate the second law of thermodynamics or the simulation of electric current using hydraulic devices are just some examples of

[1] Metaphor is a usual resource to the communication of the scientific ideas (Willson & Taylor, 2006), but this study only focused on analogy. An interesting discussion about the differences between metaphor and analogy in science education can be consulted in Aubusson, Harrison, and Ritchie (2006a).

analogies commonly used in physics. As Taylor and Dewsbury (2018) point out, the language of science is to a good degree metaphorical, and relationships of similarity between known things and unknown ones are continuously made.

The educative usefulness of analogies has also been highlighted and analysed exhaustively in science education research (Aubusson, Harrison, & Ritchie, 2006b; González, 2005; Niebert, Marsch, & Treagust, 2012; Oliva, 2004; Orgill & Bodner, 2004). In the following, therefore, we shall limit ourselves to briefly setting out what is understood by analogy (or analogue model) and what its key elements are, as well as the advantages and possible limitations of this educative resource in science education.

According to Oliva (2004) and Jonāne (2015), analogies are comparisons between different phenomena that bear some similarity at their functional or structural level. Thus, the purpose of their use is to transfer knowledge from a known or familiar situation (called the 'analogue') to an unknown one (called the 'target') (Harrison & Treagust, 2006). This also reveals some harmony with the constructivist perspective of learning since these comparisons act as bridges that allow the subject's prior knowledge to be related to the new knowledge to be learned (Glynn, 1995; González, 2005). To this must be added that an analogy often involves the learner cognitively and affectively because it allows them to connect their world with that of scientific theories, which improves their interest in and self-esteem concerning learning science (Galagovsky & Adúriz-Bravo, 2001; Harrison, 2006; Orgill & Bodner, 2004).

Oliva (2004, p. 364) makes two important clarifications in relation to the educational use of analogies: (*i*) more than just content or knowledge to be learnt, it is a process that pupils have to do (analogue transfer); and (*ii*) this process of analogue transfer demands the construction of a deeper model than the mere association of attributes between the 'target' and the 'analogue,' a model which must connect with the context in which it is elaborated to delimit its educative intention.

However, the use of analogies in science education is not without limitations, or even possible adverse effects, which should be borne in mind. Orgill and Bodner (2004) point out: (*i*) if the concept being taught is already understood, the analogy might be superfluous or distracting information; (*ii*) the analogy might be interpreted mechanically, i.e. without understanding the intended message because no attempt is made to achieve a comprehensive translation from the 'analogue' to the 'target'; (*iii*) the analogy might be interpreted as being the phenomenon itself, without considering its comparative limitations; (*iv*) the analogy might be misinterpreted, thus promoting inappropriate conceptions about the scientific issue dealt with; and (*v*) the use of analogies might generate a certain conformity in the learner that dissuades them from wanting to deepen their understanding of the concept or phenomenon itself.

All this points to the need to properly train science teachers in the use of analogies, so that they can promote this educational resource in class and be aware of its benefits and possible limitations.

News About Science in the Digital Press as an Educational Resource

For most citizens, the mass media is their main source of information about the advances in science and their repercussions (De Semir, 2003), and especially the digital press (The Spanish Foundation for Science and Technology, 2018). According to

Jarman and McClune (2007), it can be said that these are the main generators of public opinion on science-related issues at all times. Furthermore, the digital press plays an important role in directing attention and setting agendas for public discourse in relation to the development of science (García-Carmona, 2014; Höttecke & Allchin, 2020).

The digital press, together with other communication media, is substantially responsible for ensuring that citizens continue in their scientific literacy after completing their formal education (Hodson, 2008). In this sense, Miller (2004) says that a person will be truly scientifically literate when they have the ability to read and understand news from the science sections of prestigious media such as the New York Times or the equivalent digital newspapers of each country.

The science community itself is also aware of the important role of the media, in general, and encourages its members to use it to make the results of the research they carry out known to society. For example, a recent report from the *Area of Culture and Scientific Disclosure* of the Universidad Complutense of Madrid (Bayo, Mecha, & Rosa, 2018) states the following:

> The main mission of science is to improve the lives of citizens. This mission goes hand in hand with the need (…) to explain what science means and how it can improve life in society. (…) Within the framework of this mission (…) dissemination and scientific information are essential tools to achieve an efficient transfer of knowledge to society, which fosters the critical participation of citizens in scientific issues. (p. 5)

Decades ago, the illustrious Royal Society promoted the same in a report called *The Public Understanding of Science* (Council of the Royal Society, 1985):

> Scientists must learn to communicate with the public, be willing to do so, and indeed consider it their duty to do so. All scientists need, therefore, to learn about the media and their constraints and learn how to explain science simply, without jargon and without being condescending. (p. 6)

Consequently, it is reasonable that reading news with scientific content from the digital press should be part of the usual activities of science teaching and learning (García-Carmona, 2014). This can foster the understanding of contemporary scientific and socio-scientific issues, as well as develop critical and responsible attitudes towards them (Allgaier, 2010; Tsaparlis, Hartzavalos, & Nakiboğlu, 2013). Likewise, by connecting them with real scientific issues, reading news articles can provide pupils with a more utilitarian view of school science (Hobbs & Jensen, 2009). In general, such articles allow the reader to glimpse the constant change of science within the sociocultural context of each era, thus favouring a more authentic image of science (García-Carmona, 2014; García-Carmona & Acevedo, 2016; Höttecke & Allchin, 2020).

However, it should be borne in mind that news from the digital press about science is not prepared with educational use in mind. It is therefore important to assess beforehand its educative potential (García-Carmona, 2014). Furthermore, although the news from the digital press can in general be considered to be reliable because its authors usually resort to specialized scientific sources (López-Pérez & Olvera-Lobo, 2015), they themselves are not exempt from certain biases, fundamentally, for two reasons (García-Carmona, 2014): (*i*) the journalistic interpretation and/or intent in publishing the news and (*ii*) the possible simplifications or lack of rigour in their exposition due to an attempt to allow all the public to understand the message, whatever their level of scientific competence. However, this last aspect is practically inevitable when one wants to spread new scientific findings to the general population. In this regard, Taylor and Dewsbury (2018) indicate that:

> Scientists rely on metaphor and analogy to make sense of scientific phenomena and communicate their findings to each other and to the public. Yet, despite their utility, metaphors [and analogies] can also constrain scientific reasoning, [and] contribute to public misunderstandings [about science]. (p. 1; brackets added)

For all this, it is especially interesting to discuss in class which analogies are usually used in science news published in the media, as well as to critically assess their advantages and limitations in order to promote a rigorous, as well as understandable, scientific message. Given that it is recommended to start primary school pupils in regular reading of scientific information from different sources (Ministry of Education, 2014), in this study, we set out to address it in primary education teacher training.

Study Objectives

In accordance with all of the above, we proposed a qualitative study, guided by the following research question: How do PPTs' ideas about the use of analogies in science communication progress after participating in an activity oriented to (a) identifying analogies in science news published in a prestigious digital newspaper, and explain its elements; and (b) assessing the advantages and possible limitations of this resource for science communication?

Methods

Participants and Context

The participants were 33 PPTs (28 women and 5 men) aged between 19 and 23 years, with a mean age of 19.9 years. The participants made up a sub-group of the Science Teaching course (9 teaching credits) taught by the author of this study. Therefore, the PPTs selected for this study constituted a convenience sample, responding to the access to participants that was possible at the time of carrying out the study (Otzen & Manterola, 2017). Regarding the profile of the participants, most had had an unsatisfactory experience with science during their compulsory secondary education stage (12 – 16 years). So almost all of them came from academic paths unrelated to science.

The aforementioned course corresponds to the 2nd year of the Degree in Primary Education at the University of Sevilla. Among its basic objectives are that the PPTs: (*i*) reflect on and understand the purpose of basic science education; (*ii*) analyse the primary education school science curriculum; (*iii*) know what the pupils' usual conceptions and difficulties in learning science are; (*iv*) become familiar with resources and strategies for science education and evaluation; and (*v*) learn to design plans and activities to teach science in Primary Education.

Description of the Activity and Acquisition of the Information

The activity under analysis was framed within a broader unit, focused on training PPTs in basic notions about the nature of science and its teaching. This activity consisted in reflective reading of the following two news articles about the first image of a black hole, which were published in the Spanish version of the BBC News World[2] digital newspaper[3]:

- News article 1: 'How the image of the black hole shows that Einstein was right: the image, explained by one of the scientists who made it possible' (by Alejandra Martins, 12 April 2019). Available at: https://www.bbc.com/mundo/noticias-47900442 (last accessed: 13 March 2020)
- News article 2: 'First image of a black hole: how scientists combined the power of 8 telescopes in the Event Horizon Telescope to achieve a historic image' (by Redacción, 10 April 2019). Available at: https://www.bbc.com/mundo/noticias-47867134 (last accessed: 13 March 2020)

The activity attempted to focus attention on (*i*) detecting and analysing the analogies used in such news to communicate the results of the research, in this case obtaining the first image of a black hole, and (*ii*) reflecting the advantages and possible disadvantages of using this resource in science communication. The two main analogies that can be found in these news items are:

- Analogy 1: Human vision → 'Vision' of a group of telescopes

> "What we have is a real image. What happens is that our eyes do not have the resolution that the instruments have." "We cannot see it because it is very far away, we would need to have an eye that would be able to read a newspaper that someone in Paris is holding when we are sitting in New York, to give you an idea." "If we were next to the person in Paris, we would see it, it is the same. If we were just as close to the black hole with our own eyes, we would see the image that we took yesterday," he explained. (News article 1)
> Although these are massive objects, due to their distance it is very difficult to capture them. (…) The challenge is comparable to observing from Earth an orange that is on the surface of the Moon. In order to get an image of a black hole, you need a telescope with tremendous resolution capabilities. (News article 2)

[2] According to the *Socialscene* report prepared by Apple Tree Communications, BBC News World is the second most followed communications medium in the world. Report available at: https://www.appletreecommunications.com/wp-content/uploads/2017/07/socialscene-july-2017-eng.pdf

[3] An English version of this news that was also published by BBC News World at that time, in which is exposed the content treated in the two news in Spanish, is available at: https://www.bbc.com/news/science-environment-47873592

- Analogy 2: Getting the whole image → Recomposing a song

> Also, radio telescopes do not cover all the points on the planet. The scientists created algorithms to fill the gaps in the data. "You will wonder how it is possible to create an image when so much data is missing", (…). "To give you an idea of how it works, you can think of the measurements we make with the telescopes as the notes in a song". Each telescope produces measurements that correspond to the pitch of a single note. If we had telescopes at every point of the planet we could hear all the notes and listen to a perfect version of the song. But in the case of the EHT [Event Horizon Telescope], "we must recognize the song from a few notes." (…) each new observation represents a note, and each additional note makes the structure of the song clearer. (News article 2; brackets added)

In order for the PPTs to reflect on and discuss the use of analogies in science communication, they were asked the questions listed in Table 1. To implement the activity, the PPTs were organized into small groups (3 or 4 members), for a total of nine groups (G1…, G9). This decision was made for two fundamental reasons: (*i*) group interaction usually favours the elaboration of more thoughtful responses since the members of the group have to make an effort to agree on a common opinion that combines their particular points of view (Salmerón, 2013); and (*ii*) the participants were used to working in small groups in the subject, and therefore this meant continuing with the routine of organization and class work that they had been working with before. However, one is aware that group work is not always easy. So, following some recommendations for this learning dynamic (Sohr, Gupta, & Elby, 2018), during the activity, the instructor made a particular effort to ensure that each group adequately managed their agreements and disagreements while discussing the presentation of a common response.

The activity was implemented in three phases:

i *First phase: Reading the news article.* Without prior instruction, the PPTs read the article and responded as a group to the questions in Table 1. The instructor encouraged each group for their responses to be the result of an initial discussion and the subsequent consensus among all the group members. However, he clarified that if contrary opinions arose, making consensus impossible in the response, then the different opinions could be expressed. The groups were to record their initial responses in a report. This first phase, carried out in a 2-h class session, allowed the

Table 1 Questions posed to the PPTs to reflect on the use of analogies in science communication, based on the reading of the two news articles about the first image of a black hole

In the news articles you have read, the scientists interviewed resort to similes or analogies with known or recognizable things so that the general public understands their research.
Q1) Find in the texts the analogies used by the scientists in the interviews, and explain in each case how the elements of the analogy are related to those of the phenomenon or system that it represents.
Q2) What advantages and limitations do you think the use of analogies has in communicating scientific advances and discoveries to the general public? Reason your answer.

PPTs' initial ideas about the use of analogies in science communication to be evaluated.

j *Intermediate phase: Whole-class discussion of the groups' initial responses.* After responding to the questions put to them, the groups shared and discussed their opinions in class in a session of approximately 1.5 h. For it, a representative of each group presented the responses of her/his group to the other ones. Once all the groups presented their responses, a question time and debate were stimulated. The instructor moderated the discussion among the groups and made clarifications, raised additional questions to deepen and/or redirect the discussion, etc., all in order to enrich the sharing as much as possible. When the PPTs presented weakly informed ideas about the topic being analysed, the instructor tried to elicit cognitive dissonance so that they would reconsider their arguments. The purpose was to encourage the groups to reach common conclusions about the role of analogies in science communication, although without indoctrination because it was important to know what understanding levels the PPTs were capable of achieving as a learning community.

k *Final phase: The groups' conclusions after the whole-class sharing session.* After the discussion among the groups about the questions they had been set, each group had to review their initial responses, introducing all those corrections, qualifications, or extensions they considered necessary in order to improve their arguments. To do this, they had a little more than a week. The final responses from this last revision were also recorded by the groups in their reports, together with their initial responses. In this way, any possible progressions in the ideas of the PPTs about the issues discussed could be easily evaluated.

Analysis of the Information

The groups' initial and final responses to the two questions (36 responses, in total) were analysed by the instructor following the standard recommendations for qualitative content analyses (Mayring, 2000). The open nature of the questions put to the PPTs provided wide and diverse information. Therefore, following the recommendations of Jonsson and Svingby (2007), a rubric was employed to encode the responses (Table 2). This codification process was made into three stages of progressive refinement as it is exposed below.

In *stage I* of the analysis, the initial design of the rubric was made based on (*i*) the theoretical framework described above (deductive, or a priori, categories) and (*ii*) the trends or patterns observed in a first review of the responses of the groups (inductive, or a posteriori, categories) (Latorre, 2003). As a result of this, a rubric with four response levels (from 0 to 3) was obtained. However, the rubric was conceived as an open and flexible instrument which was refined throughout the analysis to obtain the best possible codification of the responses (Cáceres, 2003). Consequently, it can be said that the responses were analysed by combining inductive and deductive processes (Mayring, 2000).

About 4 months later, *stage II* of the analysis took place, in which the responses were reviewed again, and some modifications were made to their coding, which affected approximately 20% of them. The changes essentially were in the degree of

Table 2 Rubric for analysis of the group responses

	Level 3 (highest level)	Levels 2 → 0
Q1	The two main analogies are identified and at least 2 analogue-target association attributes are explained: Analogy 1: • 'Distance Paris – New York' → 'Distance Earth – Black hole' • 'Newspaper → Black hole' • 'Human eye → Event Horizon Telescope (EHT)' Analogy 2: • 'Black hole image → Song' • 'Musical note → Measurement by each EHT telescope' • 'Reconstruction of the song from the musical notes → Scientific algorithm to create the image of the black hole from different measurements'	Level 2: Either the two analogies are identified but only one of the analogue-target association attributes, or only one analogy but at least two of the analogue-target association attributes are properly identified. Level 1: One or both analogies are properly identified but in no case the corresponding attributes of the analogue-target association. Level 0: Other responses, or a blank response.
Q2	At least 2 advantages and 2 limitations of those indicated below are properly explained: Advantages: • Analogies allow us to visualize abstract concepts and phenomena that are hard to observe by relating their elements with others (analogues) that are familiar. • Analogies allow information about the phenomenon or concept to be organized and contextualized, focusing attention on its most significant aspects. • The use of analogies involves the receiver of the information cognitively and affectively, improving their interest in and self-esteem concerning science. Limitations: • The attempt with an analogy to make the phenomenon or concept it represents understandable entails a series of simplifications or losses of scientific rigour, which limit its validity or credibility. • The analogy may come to be interpreted as if it itself were the phenomenon or concept that it represents. • The analogy may be misinterpreted, giving rise to misconceptions about the phenomenon or concept. • The analogy may generate a certain conformity of understanding that discourages going deeper into the phenomenon under study.	Level 2: Properly explains just one advantage and one limitation, just one advantage and two limitations, or just two advantages and one limitation. Level 1: Properly points to either just advantages or just limitations. Level 0: Other responses or a blank response.

demand imposed on the content of the responses, the merging of some levels of responses that were differentiated in the first version of the rubric and the addition of others. For example, in the initial design of the rubric, level 3 responses were more demanding than in later versions of the rubric (initially the students were required to identify for each analogy all three of its analogue-target association attributes, but later it was considered adequate that they recognize at least two of them). Likewise, in the first version of the rubric, level 2 responses were broken down into two different levels: one that identified the two analogies, but only properly explained one of them; and another which recognized only one of the analogies, but properly explained its analogue-target association attributes.

About a month later (*stage III*), a last review of the responses was carried out in which some final adjustments were made to establish the final response coding. This was decided because such coding was the one that, in the researcher's opinion, allowed the study objectives to be met reasonably (Bengtsson, 2016).

In addition to all of the above, and in order to reinforce the objectivity of the study, sample statements will be included in the 'Results' section (Seale, 1999), i.e. data reflecting as closely as possible the reality they represent (Johnson & Christensen, 2012). In this case, these statements are excerpts from the groups' textual responses to the different questions, which will be shown as representative examples of the different coding levels that were observed of the analysis rubric.

Results

Identification of Analogies and Their Elements

The purpose of the first question was for the PPTs to recognize and explain the main analogies used in the news to explain the scientific milestone being presented, i.e. (*i*) the comparison of human vision with the 'vision' of the group of telescopes used in the research [Analogy 1], and (*ii*) likening how the image of the black hole was obtained to the reconstruction of a song [Analogy 2]. Figure 1 shows the progression of the levels of the groups' responses to this question. In the figure, the initial and final levels refer to the codification of the PPTs' responses in the first and final phases of the activity, respectively.

After their first reading of the news items (first phase), most of the groups gave a rather limited response: seven of the nine ranked at level 1, and the remaining two at level 2. According to the rubric established, although they identified one or even both analogies, the groups ranked at level 1 were found not to explain the relationships

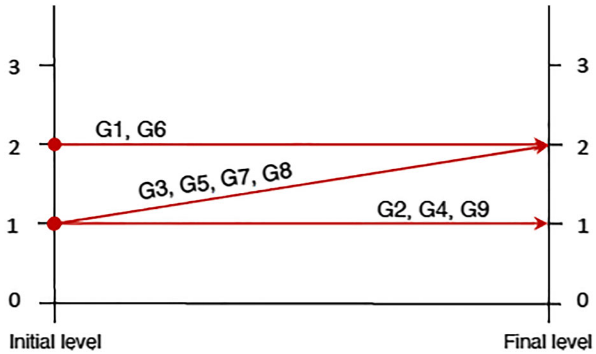

Fig. 1 Progression of the groups in the first question: Identification and explanation of the analogies used in the news items about how the first image of a black hole was obtained

between the analogue and the phenomenon/system being represented ('target'). Some responses in this regard were:

> [When the scientist says] "We cannot see it because it is very far away, we would need to have an eye that would be able to read a newspaper that someone in Paris is holding when we are sitting in New York", he is trying to explain the precision that one must have to capture the black hole image. (G3 initial level: 1; brackets added)
> [The news indicates that] the image cannot be seen because of how far away it is, giving the example that we would need to have an eye that was capable of reading a newspaper that someone in Paris is holding when we are sitting in New York. (G4 initial level: 1; brackets added)
> "Like the notes of a song" means to tell us that there have to be perfect conditions for the eight telescopes to be able to capture that photograph. (G7, initial level: 1)

Likewise, some of the level 1 groups additionally marked as analogies parts of the news article that are just simple comparisons. For instance:

> It compares the black hole with a door in which what enters would be like dying, because you cross it and you can no longer return. (G4, initial level: 1)
> [The news article] highlights the similarities between crossing a black hole's event horizon with dying, since once you cross that "door", you cannot come back. (G5, initial level: 1; brackets added)
> "The shape can be more flattened, [sic: "más achatada" in the original Spanish] like a rugby ball." With this definition, it is showing us the appearance of the black hole. (G7, initial level: 1)

Or they give explanations of the methods and techniques used in the research:

> Use [is made] of colour to explain the effect created by the wavelengths. [Also] it explains gravity to us, situating us in cities like London or Washington where we verify that it does not vary. (G5 initial level: 1; brackets added)
> We need to resort to the interference pattern because our eyes are not able to see that far, and they do not have the resolution that instruments have. (G8, initial level: 1)

The two groups at level 2 explained reasonably well the correspondences between the analogues and the elements represented of the 'target,' relating them to at least one of the analogies. Group G1, for example, did so for only Analogy 2: 'The musical notes form a song in the same way that the different partial photographs of the black hole come together to form an overall image. Each note is what each telescope does.' (G1, initial level: 2).

Group G6 went a little further. They explained Analogy 2, identifying two analogue-target association attributes, and tried to describe Analogy 1 as well. However, in this latter case, they only explicitly identified one association attribute, for which reason, in accordance with the rubric, this group's response was coded at level 2:

> "… like the notes in a song." The measurements of each telescope correspond to a musical note. Since we have telescopes at every point on the planet, we could mount a complete photograph, just as if they were notes we could listen to a song. The song would be the image. [Analogy 2]. "… we would need to have an eye that was capable of reading a newspaper that someone in Paris is holding when we are in New York…" The newspaper would be equivalent to the black hole. If we were next to a person in Paris, we would see it, as it would be with the black hole, we would have to be just as close. [Analogy 1] (G6, beginning level: 2; brackets added)

The discussion the groups held, sharing their ideas, during the instructor-moderated whole-class session (intermediate phase) gave them the opportunity to revise their initial responses (final phase). As a consequence, four of the nine groups showed a progression in their responses from level 1 to level 2. An example of these final responses is that of group G8, which was initially ranked at level 1:

> We would need an eye that was capable of reading a newspaper which was in Paris. The newspaper is equivalent to a black hole and Paris is equivalent to the Universe. [Analogy 1]. Just as a song is made up of musical notes (what each telescope does), this image is formed by measurements. So: "If we had telescopes at every point on the planet, we could hear all the notes and listen to a perfect version of the song." *I.e.*, the notes of a song are the different images [partial measurements] that make up the final image. [Analogy 2] (G8, final level: 2; brackets added)

Groups G1 and G6 improved their initial responses slightly (level 2), but not enough to reach the maximum response level (level 3). For example, group G1 added Analogy 1 to their initial response, but only identified one of its analogue-target association attributes (the underlining is the part added to the initial response):

> The musical notes form a song in the same way that the different partial photographs of the black hole come together to form an overall image. Each note is what each telescope does. <u>[Also] recognizable objects are used as a scale to give the reader an idea. The observation of a black hole is likened to reading a newspaper that was in Paris. The newspaper is equivalent to the black hole</u>. (G1, final level: 2; brackets added)

The remaining three groups (G2, G4 and G9) stayed at level 1 in accordance with what was indicated in the rubric because they did not add anything sufficiently notable to their responses. For example, group G9 simply added the following comparison: '(…) it is like seeing an orange that is on the surface of the Moon from Earth. This is used to explain that it is somewhat difficult to see.' (G9, final level: 1).

Finally, it is worthy of note that no group reached the maximum response level (level 3) as set out in the analysis rubric. Likewise, no group related the scientific algorithm created in the research that gave the photograph of the black hole with the process itself of reconstruction of a song, within Analogy 2.

Advantages and Limitations of the Use of Analogies in Science Communication

The second question sought to get the PPTs to reflect on the advantages and possible limitations of using analogies in communicating scientific research. In the analysis of the responses in this regard, as has been noted above, we took into account the findings of educational research with respect to the use of this resource in teaching and disseminating science. Figure 2 represents the progression of the groups in this matter. As can be seen, after their first reading of the news articles (first phase), the groups' initial responses were fairly evenly distributed between levels 1 and 2.

There stands out as the most characteristic feature of level 1 responses that those groups only properly indicated advantages in the use of analogies, but no limitations. Four of the five groups (G4, G5, G6 and G7) at this level referred to analogies' role in making abstract phenomena and concepts more understandable, giving in support arguments such as the following:

> The advantage is that, by associating concepts that are so technical within the scientific field, and which we do not deal with or know about, with things that we are accustomed to dealing with in real life, it makes it possible for us to understand them better and more easily, which facilitates understanding. (G4, initial level: 1)
>
> The use of analogue models is truly useful in getting this knowledge over to people who have a medium-to-low educational level, since it helps them to understand and retain more effectively knowledge that explained in some other way would be beyond their intellectual reach. (G5, initial level: 1)

The other level 1 group (G8) only made a brief mention of the usefulness of analogies to attract readers' interest in science-related news: '(…) It can attract the attention of people who are not immersed in the scientific world.' (G8, initial level: 1).

With regard to the responses of the level 2 groups, they all pointed to the advantages of using analogies to make scientific knowledge more accessible, while, among the possible limitations, they noted that excessive simplification of the fact or phenomenon may lead to a loss of scientific rigour. An example of such responses is the following:

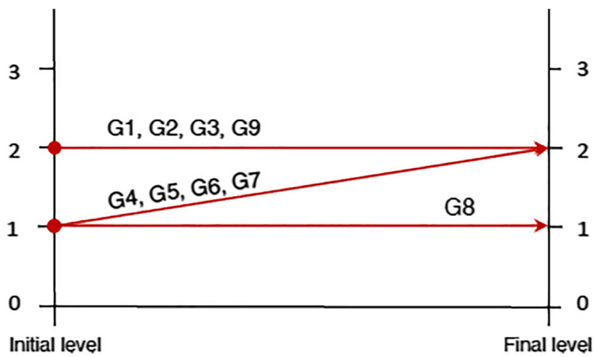

Fig. 2 Progression of the groups in the second question: Determination of the advantages and limitations of the use of analogies in science communication

> As advantages, we believe that the use of analogies facilitates understanding the topic at hand and helps create a visual representation [of the phenomenon or scientific discovery]. And, as disadvantages, we believe that (…) the use of language that is more colloquial can lead to a loss of rigour and can make the fact seem simpler than it really is. (G1, initial level: 1; brackets added)

In addition to the above arguments, two level 2 groups (G2 and G3) added that another limitation of the use of analogies is that the reader might misinterpret them, and thus acquire a wrong conception of the phenomenon or fact being represented, or have doubts about the credibility of the news:

> (…) Among the drawbacks, we consider that the use of analogies may lead to (…) a possible loss of rigour. Furthermore, it may also distort the original [scientific] message. (G2, initial level: 2; brackets added)
>
> (…) we can mention as a drawback the fact that they may not be formal explanations, and may raise doubts about their credibility. Together with this, being analogies, on many occasions they fail to be understood or they generate different interpretations according to each person. (G3, initial level: 2)

After sharing their initial responses in the whole-class session (intermediate phase), the groups revised them to reflect their final opinions and arguments on the question put to them (final phase). Four of the nine groups (G4, G5, G6 and G7) showed a progression in their responses from level 1 to level 2.

The most notable thing about the improvement of these groups is that they all added to their initial response the same limitation of analogies: the possible loss of scientific rigour when trying to simplify the message to make it accessible to all kinds of audience. For example, '(…) possibilities of distorting the original message, so there is a loss of scientific rigour [by making] a simplification of the entire process that actually led to the photograph.' (G5, final level: 2; brackets added).

As with the first question, neither in this question was level 3 reached. Furthermore, no group mentioned as an advantage of analogies that they seek to contextualize the information so as to focus attention on the most significant aspects of the phenomenon. And with respect to the possible limitations, it was not mentioned that the readers might take the analogy as if it were the actual concept or phenomenon represented, nor that its use may generate a certain conformity and loss of any interest in going deeper into the object of study.

Discussion

The results of this study indicate that, overall, the PPTs showed a moderate progression in their conceptions of the use of analogies in science communication. This global assessment is estimated on the basis of two considerations. First because, although progressions were observed in the groups' responses, none of them reached the maximum level of response (i.e. level 3) established in the rubric. This indicates that the maximum level was perhaps an educational goal too high for the participants in the study, who had not had previous experiences in analysing or reflecting on the use of analogies in science communication.

Second, because in both of the activity's questions, about half of the groups experienced notable improvements in their responses. However, it should be said that there were already in the first phase groups that were at a high response level (level 2, with 3 being the maximum), especially for question 2 (4 out of 9 groups). Likewise, there were final responses which had not been completed sufficiently to be assigned to the next level up but did show some kind of improvement compared with the initial case. Therefore, it can be said that the activity in general had a positive educative effect that was in accordance with its purposes, above all taking into account the characteristics of the participants, i.e. teacher training students with a limited academic background in science at school. This highlights the educative potential of reading and analysing science news in the daily press both for science education (García-Carmona, 2014) and for the public understanding of science in general (Miller, 2004).

With regard to the identification of analogies and their elements in the science news articles that were analysed, the PPTs started out with quite limited responses. Most of the groups detected some of the analogies in the news articles but did not describe their analogue-target association attributes. However, after the whole-class session in which they shared their views, about half of the PPTs added some of these association attributes to their responses. In these, allusions were found to the three attributes considered in the rubric for Analogy 1 (human vision – 'vision' of a group of telescopes): 'distance Paris – New York' → 'distance Earth – black hole'; 'newspaper → black hole'; and 'human eye → EHT.' For Analogy 2, however (obtaining the photograph – reconstruction of a song), no group referred to this association in their responses. Although the algorithm cited in the news was mentioned during the whole-class session, perhaps its omission in the groups' final responses was because the PPTs had not really understood it. As stated by Niebert et al. (2012), teaching science based on analogies requires far more than the fact of connecting analogues and targets—among other factors, it requires that the learners' pre-existing conceptions about and mastery of the science topic being dealt with should be taken into account. In this sense, we consider that, although the news articles used in this study present information that the PPTs can in general understand, there are parts of those items that involve a high degree of scientific specialization (notions of the Theory of Relativity, the idea of gravitational field, the concept of a scientific algorithm…). Therefore, when using science news articles in the press in teacher training, one must always assess beforehand whether or not the science content the items are addressing is too complex for the students.

With respect to the advantages and possible limitations of the use of analogies in science communication, the advantage that was most evident from the outset for the PPTs was that the use of analogies makes scientific knowledge more accessible to people who are not specialists in the subject (González, 2005; Oliva, 2004). Instead, only a minority made any reference to possible limitations of analogies—specifically, the potential loss of rigour in the information (Taylor & Dewsbury, 2018), and the possibility that they might lead to inappropriate conceptions of the phenomenon or discovery being described (Brown & Salter, 2010; Orgill & Bodner, 2004). After the whole-class session discussing the initial responses, most groups accepted the possible loss of rigour as being the main limitation of the use of analogies in science communication. The PPTs also mentioned the usefulness of analogies in fostering readers' motivation or interest in the science content being dealt with (Harrison, 2006), albeit in a minority form.

Conclusions and Implications

All of the above indicates that an analytical reading of science news is a good resource in PPTs' education on the use of analogies in science communication. Indeed, the results achieved offer helpful and hopeful insights into PPTs' understanding and use of analogies in science, and in a knowledge-rich society, knowing good science from Fake news is ever more paramount, etc. (Höttecke & Allchin, 2020).

Even so, the reading of science news for analysing the use of analogies in science communication should be complemented with other types of activities. Examples might be activities to analyse analogies drawn from the history of science (Acevedo, 2004), or activities that evoke examples of familiar situations and promote the use of everyday materials to represent phenomena in the different domains of school science (Aragón et al., 2014; Emig et al., 2014; Haglund et al., 2012), among others. In general, these would be school activities that invite the learner to participate in practices of scientific modeling (Galagovsky & Adúriz-Bravo, 2001), since analogies are no more than a mediating resource between scientific models and the school models that are constructed from them as a base (González, 2005).

Likewise, it would be interesting to promote activities that encourage PPTs' oral and written communication of their own scientific ideas, with the support of well-chosen analogies so that the message can be understood by their peers. For example, in the context of a school science inquiry, the PPTs could be asked to communicate their conclusions both formally (in a purely scientific way) and analogically (translated into more familiar language), but laying out clearly the attributes of the analogue-target association. With the appropriate scaffolding provided by the teacher, this can contribute to developing the cognitive-linguistic skills of science, such as description, comparison, explanation and reasoning, that are essential in the construction of school scientific knowledge (Sanmartí, Izquierdo, & García, 1999).

It is reasonable to expect that such short teaching interventions will not make it possible for PPTs to consolidate any broad and deep learning about the use of analogies in science. However, there is no practical choice but to opt for new activities whose implementation does not overload already extensive teacher training programs. Likewise, short interventions such as that presented here are examples of a realistic adaptation of innovative educational proposals to the habitual development of such teacher training programs, and this may be motivating for other teacher educators to be encouraged to implement them with their students.

Finally, it must be added that the present results would, in a strict sense, not be applicable to other contexts since they came from a study sample of participants chosen for convenience. Nonetheless, these results may be found to constitute an interesting referent for new research in primary teacher training contexts with similar characteristics (Elliot, 2000). This is mainly because they put forward a novel line for science teacher training in the use of analogies in science communication, using as an educational resource the science communication media that are most influential in society.

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