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Gimenez, Julio; Baldwin, Mark; Breen, Paul; Green, Julia; Roque Gutierrez, Ernesto; Paterson, Richard; Pearson, Jayne; Percy, Martin; Specht, Doug and Waddell, Guy (2020). Reproduced, reinterpreted, lost: Trajectories of scientific knowledge across contexts. Text & Talk, 40(3) pp. 293–324.

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Version: Version of Record

Link(s) to article on publisher's website:
http://dx.doi.org/doi:10.1515/text-2020-2059

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DE GRUYTER MOUTON Text&Talk 2020; 40(3): 293–324

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Reproduced, reinterpreted, lost: Trajectories of scientific knowledge across contexts

https://doi.org/10.1515/text-2020-2059

Abstract: This article reports on a research project that uses two innovative heuristics to examine the changes that texts – produced to disseminate new scientific knowledge – undergo when they travel across space and time. A critical analysis of such transformations would enhance our understanding of the processes involved in knowledge dissemination and inform the practice of communicating scientific knowledge to a variety of audiences. Based on our study of 520 closely linked science and science-related sources collected over 12 months in 2016, we argue that when scientific knowledge is re-contextualized to be disseminated to different audiences, it is not *simply* rephrased or simplified to make it more accessible. Rather, it also undergoes transformational processes that involve issues of social power, authority and access that require new analytical tools to surface more clearly. We report on the methodology of the study with a particular focus on its heuristics, and the transformations that result from a critical analysis of the data collected. We finally discuss a number of theoretical and practical implications in relation to contemporary practices for re-entextualizing scientific knowledge.

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Keywords: text trajectories, re-entextualizing, scientific knowledge, science communication, heuristics, knowledge dissemination

1 Introduction

In contemporary communication practices, written and spoken texts are recycled in a variety of ways and across a range of contexts. An interview with a politician may be first recorded and later transcribed before it is printed in a newspaper, to be subsequently discussed on blogs and television programs. When texts are re-contextualized, that is, placed in a different context, they are often transformed, acquiring new and sometimes different positioning, roles and functions (Blommaert 2005). These transformations, which result from altering a text so that it meets the real or perceived expectations of different audiences, have received increased research attention recently due to critical considerations of the roles of interconnected contexts in communication (e. g. Blommaert 2005; Budach et al. 2015; Kell 2015; Woydack and Rampton 2016). Studies in academic publishing (e. g. Lillis and Curry 2010), education (e. g. Gourlay et al. 2015), social work (e. g. Hall et al. 1999; Lillis 2017), science (e. g. Myers 2003; Luzón 2013), and witness accounts to the police (e. g. Rock 2017) have highlighted the importance of investigating such transformations in order to gain a better understanding of the processes involved in the re-contextualization of texts. In STEM (Science, Technology, Engineering, and Mathematics) this understanding has become paramount given the growing importance of texts in communicating new knowledge beyond the scientific community (Rödder et al. 2011; Burningham et al. 2012; Simis et al. 2016), and the rapid growth of popular science publications since the mid-1990s (Leane 2017).

There is, however, not much published research that specifically tracks such transformations in scientific texts. In particular, we know very little about the processes through which changes to scientific texts are made in an attempt to disseminate new knowledge to different audiences: scientists, popular science readers, and the wider public. This gap in the literature seems rather unexpected given the increased attention that communication between scientists and the public has received recently (e. g. Cook et al. 2004; Burningham et al. 2012; Gimenez et al. 2017). Our research thus aims at contributing to our understanding of the processes of language transformation and meaning mobilization involved in the re-contextualization of new scientific knowledge when it travels across contexts (Rymes 2012; Kell 2013, 2015). Our study also adds to the existing literature by using new analytical tools which help issues of power, authority and access implicated in such processes surface more clearly.

This article thus reports on two innovative analytical tools, referred to as the *heuristics* hereafter, used to examine the changes that texts produced to disseminate new scientific knowledge undergo when they travel across contexts (Gimenez and Roque Gutierrez 2016; Gimenez et al. 2017). To problematize an already complex process, we argue that when scientific knowledge is re-contextualized it is not *simply* rephrased or simplified to make it more accessible to diverse audiences; a reason commonly reported for such transformations (Cook et al. 2004). Rather, we contend that the re-contextualization of scientific knowledge is more than just a textual exercise; more importantly, it is a series of processes in which knowledge is re-interpreted, changed, and even lost as a result of issues of power, authority and access.

In this respect, the questions our work explores are: What patterns does re-contextualized scientific knowledge follow when it travels across different contexts? What transformations to scientific knowledge can be observed in such travels? How can these patterns and transformations be best captured? What issues of social power, authority and access surface when scientific knowledge is re-contextualized? These are important considerations which this article addresses so as to gain a better appreciation of the processes involved in the dissemination of new scientific knowledge and inform the practice of communicating new knowledge to different audiences.

We first offer a critical review of the literature that has informed our research. We then report on the methodology of the study with a particular focus on the heuristics designed for the analysis of trajectories of new scientific knowledge. Next, we present a critical analysis of the data of the study, which highlights the patterns in text trajectories and the linguistic and rhetorical transformations that occur. We finally discuss a number of theoretical implications and practical applications with an aim to help to improve communication between scientists and non-scientists.

2 Review of relevant literature: Trajectories of scientific knowledge and text transformations

Re-contextualization studies have called for a focus on multiple instances of re-contextualization to be able to trace the changes that texts experience in their trajectories (e. g. Bernstein 1990; Linell 1998; Linell and Sarangi 1998; Myers 2003; Blommaert 2010; Rymes 2012; Luzón 2013; Lillis and Maybin 2017). Together with this call, there has been a growing interest in meaning-making processes in written texts as they travel across contexts (Kell 2015, Kell 2017) in an attempt to gain a better understanding of what is involved in such processes.

Previous debates on the dissemination of scientific knowledge have considered public communication of science as a continuum of "competing discourses" (Myers 2003: 267), rather than a series of discrete episodes in which specialized discourses are translated into simplified texts for passive, non-scientific audiences (e. g. Myers 2003; Bucchi 2008; Luzón 2013). Myers (2003: 267) has convincingly argued that to understand this continuum, text analysts should "question who the actors are, how the various discourses interact, what modes are involved, and what is communicated" to help processes of dissemination become clearer. Similarly, Luzon (2013: 429) has contended that it is out of the interaction between specialist and popularized discourses that scientific knowledge is constructed and thus the dissemination of such knowledge to diverse audiences "is not a matter of simplification or 'translation,' but of re-contextualization". Our work builds upon this body of literature, elaborating on existing debates by contributing more processual views of the mobility of meaning making involved in the dissemination of scientific knowledge.

Like other texts, scientific texts may assume "different contingent configurations" (Bucchi 2008: 72) in their trajectories. These configurations result from a process that involves lifting a text from its original time and place to be re-contextualized in a new context. This process usually involves repurposing the intended meanings of the original text to meet the new focus and real or perceived expectations of a new audience and thus the need to examine multiple instances of re-contextualization.

The literature on the analysis of such instances has created a number of related theoretical constructs to describe re-contextualization processes. For instance, Hanks (1989) used "centering", "decentering", and "recentering" to refer to the processes of contextualizing a text, de-contextualizing and re-contextualizing it respectively; Blommaert (2005) has referred to "re-entextualization" to describe how texts are de-contextualized, refocused and reorganized, following a number of transformations, and Kell (2015) has termed the study of these processes "trans-contextual analysis". Despite the differences in terminology, these works claim that through the processes of re-contextualization not only is the language of texts reconfigured but also, and probably more importantly, new meanings and associations are created as they travel across space and time.

For our research, we have borrowed Blommaert's (2005) term 're-entextualization' (a concept introduced earlier on by Silverstein and Urban 1996) and applied it to the analysis of the trajectories of scientific texts used for disseminating new knowledge. As Blommaert (2005: 47) explains, through re-entextualization discourses become "associated to a new context and accompanied by a particular metadiscourse which provides a sort of 'preferred reading' for the

[new] discourse". In this sense, re-entextualization reflects more closely the processes and changes manifested in the data of our project. The two key terms in our work are: (1) 'entextualization' which we use to refer to the process by which scientific knowledge is originally represented in written, spoken or graphic form; and (2) 're-entextualization' which we use when entextualized scientific knowledge is transformed through processes such as re-interpretation, re-organization, and re-focusing. These two terms and the processes associated with them are explored later in the article.

In line with this literature, we argue that when scientific knowledge is re-entextualized, it is also 're-accentuated' (Bakhtin 1986), acquiring new positionings, purposes, roles and functions. Although re-entextualized knowledge may still show traces of the original occasion of production, it is often transformed with regard to its original entextualized form and re-inscribed with new meanings. The *re-interpretation* of the meanings of the original text that occurs in re-entextualization involves changes of many kinds, including alterations, distortions, invigorations and distillations, depending on the specificities of the case.

These re-interpretations often result from two related interpretative processes: the writer's understanding of the meanings in the original entextualized knowledge, and his/her perceptions of the expectations of different audiences. In this sense, re-entextualization is not just an exercise in which texts are modified to make them clearer or simpler, for instance, and more accessible (Cook et al. 2004), which embodies a rather naïve view of the process. As Bauman and Briggs (1990) have argued, re-entextualization is an act of control by which knowledge (or parts of it) may be re-produced or silenced, claims may be given or denied authority, and access to associated resources may be either granted or denied. As we discuss below, this act of control made possible by re-entextualization raises concerns about the social distribution of power, authority, and access involved in the processes of scientific knowledge dissemination. Control is also about the 'versions' of knowledge that reach different audiences, an important consideration in this time when fake news appears to be commonplace.

In their seminal paper, Bauman and Briggs (1990) argued that recontextualization is a transformational process. Therefore, when attempting to analyze it, we must "determine what the re-contextualized text brings with it from its earlier context(s) and what emergent form, function, and meaning it is given" (Bauman and Briggs 1990: 75) in its new context. This would allow for transformations (e. g. what is re-produced, re-interpreted, and lost) to surface more clearly. They encouraged analysts to ask questions such as: Which elements of the original text are repeated? Which are quoted? Which elements are embedded? Which formal elements (e. g. structures) are transformed or remain the same? Are markers of person, space, time maintained or transformed? What relationships are established between the emerging discourse and its new context? Although their work focused on spoken discourses, these questions are also relevant to the study of the re-entextualization processes of written discourses and thus, together with Bauman and Briggs' early discussions on re-entextualization, they have informed the design of the heuristics for the present study which is discussed in Section 3. An examination of such transformations would thus require considering multiple instances of re-entextualization rather than the analysis of single texts (Kell 2015), which is the methodological and analytical perspectives we have adopted in our study.

Alongside Bauman and Briggs (1990) and Silverstein and Urban (1996), Blommaert (2005) has argued that re-entextualization practices depend heavily on power (e. g. practices that include certain readers and exclude others) and accessibility to intellectual, linguistic and material resources (e. g. a specific type of knowledge needed to understand a text) – both key elements for social inclusion and exclusion (Gee 1999). Blommaert (2005: 62) illustrates his argument with stories of asylum seekers in which their original stories are followed by "a number of administrative text-making procedures" such as reports, letters, and official interpretations in summaries. Like in the game called '(broken) telephone' in which original messages are distorted as they pass on from one person to another, the final version of a narrative, contends Blommaert (2005: 63), may not actually involve replication of their original story but rather "far-reaching transformations", a process also observed in the re-contextualization of scientific knowledge as we discuss below.

As this review has shown, research on text trajectories and the resulting transformations has attracted considerable attention in recent years. However, we still know very little about the particular processes and specific transformations that scientific knowledge undergoes when it is re-entextualized for dissemination purposes.

3 Data and methods

3.1 The bank of materials

The materials for the present study were selected from 520 closely linked science and science-related sources, including scientific journals, newspapers and news websites, over 12 months in 2016. The breakdown of sources is presented in Table 1. These sources were chosen for their circulation and

Table 1: Breakdown of sources.

Source type	Number	Percentage
Scientific articles (entextualized knowledge)	130	35%
Popular science magazines (re-entextualized knowledge)	163	31%
Newsmedia (re-entextualized knowledge)	227	44%

audience reach. They also provide a variety of different publications that cover most reader profiles on the communication continuum. For instance, *METRO* is a free newspaper with a circulation of over 1,400,000 copies, published in the United Kingdom and distributed mainly on public-transport services and stations. *The Mail Online*, another source, is the digital version of the British newspaper the Daily Mail although the newspaper and the website are run as separate enterprises with different editorial teams. *The Mail Online* attracts over 11 million visitors. The journals in our data bank include publications such as the *Journal of Neuroscience*, a peer-reviewed scientific journal whose impact factor is twice as high as the next highest journal in the field, and *Nature*, a peer-reviewed journal in science and technology with a high impact factor.

The materials were thematically organized and constituted a bank of entextualized scientific knowledge on STEM-related themes. Once a particular text was randomly chosen from the data bank, it was initially analyzed and its associated texts (e. g. sources, re-productions) were traced. If no associated texts could be found, the chosen text was discarded as it would not be possible to trace its trajectory. Trajectories were needed as, in juxtaposition to existing research, our study focuses on the analysis of multiple instances of data in an attempt to understand the processes involved in knowledge re-entextualization (Kell 2015, 2017).

The tracing process was guided by a reference provided in the text or by searching databases. In the case of newspapers and news websites, the tracing process connected the piece of news with other sources such as popular science magazines like *New Scientist* and articles in scientific journals. Once this process was completed, a trajectory for each text was traced to represent the journeys that a particular piece of scientific knowledge had undergone. This produced 340 trajectories out of the total 520 texts. The typical trajectories in our data are presented in Figures 3–5 below, and a list of the texts selected for this article is provided in the Appendix.

3.2 The heuristics

As mentioned earlier, the main aim of our research is to examine the processes involved in the re-entextualization of scientific knowledge for dissemination purposes. To this end, we developed two innovative heuristics which provide new insights onto the complexities involved in such processes.

We first designed *ETEK* (Episodes in Trajectories of Entextualized Knowledge), a heuristic for tracing the trajectories of entextualized scientific knowledge (see Figure 1). At the centre of each episode we find social actors (e. g. scientists, journalists) and their artifacts for knowledge dissemination (texts and visual representations), both interacting in a given space and time. This heuristic allowed us to have an overview of the *patterns of trajectory* followed by scientific texts in a variety of contexts. The second heuristic, which we call *TEREF* (Textual Elements and Rhetorical Functions), gained us a more micro perspective of the transformations undergone by entextualized scientific knowledge (see Table 2). We used *TEREF* to identify linguistic (e. g. simplified lexis) and rhetorical (e. g. attribution of authority, imagery persuasion) transformations made to scientific knowledge when disseminated to different audiences. The sections that follow provide a detailed description of both heuristics.

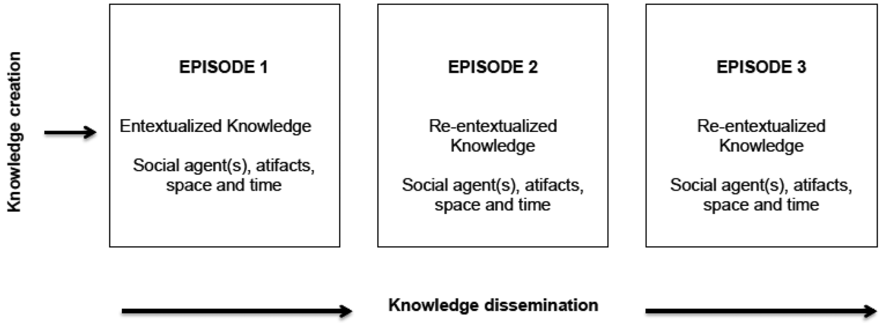


Figure 1: ETEK- A heuristic for analyzing trajectories of entextualized knowledge.

3.2.1 ETEK: A heuristic for analyzing trajectories of extentualized knowledge

The term ‘trajectories of entextualized knowledge’ refers to the processes of entextualization and re-entextualization of scientific knowledge. These processes comprise a series of episodes that shows how knowledge travels across

Table 2: TEREF- A heuristic for analyzing knowledge transformation.

	Episode 1: [artifact source]	**Episode 2: [artifact source]**	**Episode 3: [artifact source]**
Data →	**Artifact text + graphs**	**Artifact text + graphs**	**Artifact text + graphs**
Levels of analysis ↓			
Textual elements			
Structure			
Grammatical features			
Lexis			
Etc.			
Rhetorical functions			
Attribution of authority			
Meaning making/re-making			
Visual purpose			
Etc.			

space and time and provides a view of the social agents and artifacts involved in dissemination practices. This is represented in Figure 1. As shown in this figure, the first episode in the dissemination process entails entextualizing scientific knowledge for a particular audience (e. g. readers of a scientific journal). The subsequent episode or episodes involve re-entextualizing, that is, reorganizing, refocusing and re-contextualizing it in order to reach a different audience (e. g. readers of scientific magazines, readers of popular media websites). It is worth noticing at this point that although the episodes may appear to be rather neat and discreet spaces in terms of the social actors and artifacts they represent this was not always the case. Rather than being very sharply delineated, many episodes in the database showed traces of previous episodes and in some instances even replicated sections of artifacts in them. We discuss this in more detail in Section 4.2 below.

In Episodes 2 and 3, as knowledge is re-entextualized, the social actors involved in such episodes would make their own interpretations of the knowledge presented to them, and would have their particular aims when re-entextualizing it to communicate with a new audience, often projecting their own forms and meanings onto the new instance of re-entextualized knowledge. This act of recreation of forms and meanings, as Bloomaert (2005: 63) explains, becomes a 'preferred reading' for the new text as discussed below. The recreation processes become clearer when examining artifacts with our second heuristic as explained in the next section.

3.2.2 TEREF: A heuristic for analyzing knowledge transformation

The design of *TEREF*, the second heuristic for our study, has been informed by concepts developed by Bauman and Briggs (1990), Lillis (2008), and Lillis and Curry (2010). Lillis's and Lillis and Curry's "textual and rhetorical framework" (Lillis 2008: 368) has informed the development of similar elements and functions in *TEREF*, and Bauman and Briggs's earlier work has guided our choice of rhetorical functions.

As shown in Table 2, *TEREF* comprises two interrelated levels of analysis: Textual Elements (e. g. lexis, grammatical features such as active/passive voice, and impersonal structures), and Rhetorical Functions (e. g. indexical features such as personal pronouns, writer's positioning in relation to text and audience) which also include rhetorical changes through imagery (e. g. how and to what ends images are used).

Whilst *ETEK* has proved a useful heuristic for identifying the trajectories of entextualized knowledge for dissemination purposes, *TEREF* has facilitated the identification of the textual elements that have been transformed and new rhetorical functions that have been created as entextualized scientific knowledge travels. Together, these two heuristics have not only offered us access to the modifications undergone by scientific knowledge but also made it possible for issues of social power, authority and access to manifest themselves more clearly as we discuss in Section 4.

3.3 Application of the heuristics

Once designed, the heuristics were tested on a number of artifacts from the bank of materials that constitutes the empirical data for the study. Examples of their application are provided in Figure 2 and Table 3. Figure 2 illustrates the trajectories of a piece of scientific knowledge from its original entextualization in the *Journal of Neuroscience* (a scientific journal) through its first re-entextualization in the *New Scientist* (a scientific magazine), and to its second re-entextualization in the *Mail Online* (the online version of a British tabloid). Table 3 shows an analysis of some of the main textual elements and rhetorical functions in the artifacts shown in Figure 2.

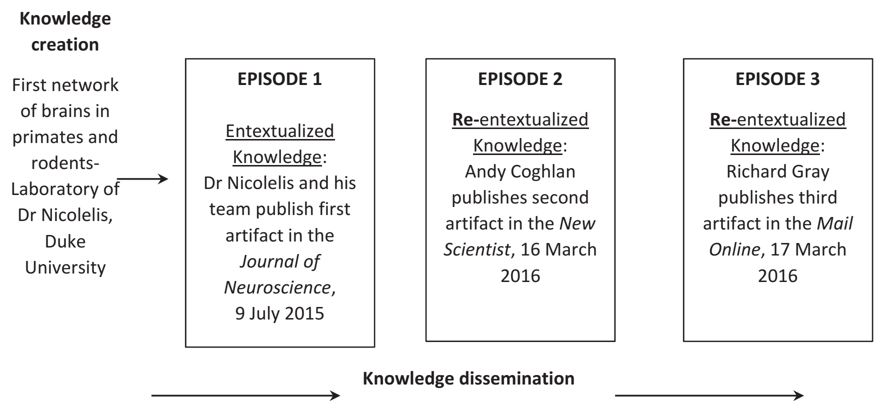


Figure 2: Application of ETEK.

4 Results and analysis

In this section we first present the results from applying both ETEK and TEREF. We then analyze these results in an attempt to answer the questions posed for the study.

4.1 Main patterns in the trajectories of entextualized knowledge

As to the patterns that entextualized scientific knowledge follows when it travels, three patterns have emerged as recurrent from analyzing the data in our study. Pattern 1, illustrated in Figure 3, consists of an entextualization and a re-entextualization episode, and represents 17% of the trajectories in the data bank (see Table 4).

This pattern shows the trajectory of a scientific text from its entextualization in *Procedia Engineering*, a high-quality collection of conference proceedings published by a major science publisher (Elsevier), to *BBC Future*, the commercial news website of the British Broadcasting Corporation (BBC) in the United Kingdom. As can be seen in Figure 3, Episode 1 (knowledge entextualization) in the trajectory is the direct source for Episode 2 (knowledge re-entextualization) which has been written for a different, less academic audience.

Pattern 2, illustrated in Figure 4, shows a slightly different journey and represents a quarter of the trajectories in the data bank.

Table 3: Application of TEREF.

	Episode 1: Journal of neuroscience	**Episode 2: New scientist**	**Episode 3: MAIL online**
Biographical information	Hartmann, K., Thomson, E.E., Zea I., Yun R., Mullen P., Canarick J., Huh A., and Nicolelis M. A. (2016). *Journal of Neuroscience*, 36(8):2406–24.	Coghlan, A. (March 16, 2016). Rats learn to sense infrared in hours thanks to brain implants. *New Scientist*, 3066: 45. Available at https://www.newscientist.com/article/2080671-rats-learn-to-sense-infrared-in-hours-thanks-to-brain-implants/	Gray, R. (March 17, 2016). Could we soon have superhero NIGHT VISION? Brain implants could give us 'sixth sense' by making us see infrared. *Mail Online*. Available at http://www.dailymail.co.uk/sciencetech/article-3496895/Could-soon-superhero-NIGHT-VISION-Brain-implants-rats-sixth-sense-making-infrared.html
Title/Headline	**Embedding a Panoramic Representation of Infrared Light in the Adult Rat Somatosensory Cortex through a Sensory Neuroprosthesis**	**Rats learn to sense infrared in hours thanks to brain implants**	**Could we soon have superhero NIGHT VISION? Brain implants could give us a 'sixth sense' by making us see infrared**
Data →	To work properly, cortical sensory neuroprosthetics will require that the adult brain be plastic enough to continuously process real-time streams of synthetic information sources, and then…	BRAINS get data about the world through senses- sight, hearing, taste, smell and touch. In a lab in North Carolina, a group of rats is getting an extra one. Thanks to implants in their brains, they have learned to sense and react to infrared light.	It has been put to good use by comic book superheroes and by alien predators hell-bent on wiping out mankind, but soon humans could also be able to see infrared light. Scientists have used brain implants to give rats a 'sixth sense' that enables them…

Levels of analysis ↓			
Textual: Lexical changes	Technical	Non-technical and informative	Non-technical and evocative
Rhetorical: Focal changes	Experiment and processes	Participants and results	(Assumed) Implications for readers
Changes in attribution of authorship/authority	Direct (“we”)	Partial (“his team”)	Anonymised (“the scientists”)
Changes in visual purpose	Data-display: used to visually represent data, the experiment, and the processes	Representational: used to offer a comment on content (e. g. power of perception)	Expressive: used to create an impact on the reader (infrared light, goggles for night vision, science fiction film – Predator)

Table 4: Distribution of patterns in the bank of materials.

Trajectories	Pattern 1	Pattern 2	Pattern 3
Total number (340)	58	85	197
Percentage (100%)	17%	25%	58%

n of texts = 520

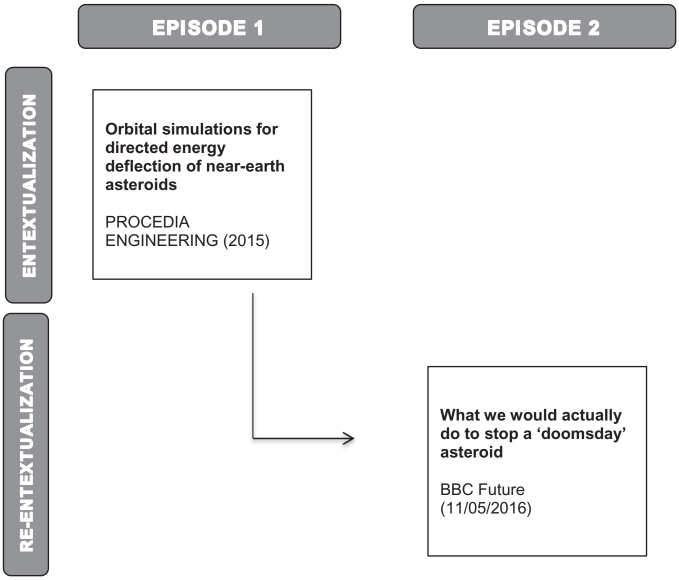


Figure 3: Trajectory pattern 1.

As the figure shows, Episode 1 (entextualized knowledge) is the original source for two different episodes. The two re-entextualizing episodes have different social actors and artifacts and were written for difference audiences. In the case of Episode 2A the resulting text was written for *The Guardian*, a British daily newspaper whose readership is generally considered to be on the ‘centre-left’ of British political opinion. The text in Episode 2B, on the other hand, was published in *TakePart*, a digital news and lifestyle magazine aimed at raising awareness of social advocacy efforts.

Figure 5, the most recurrent pattern in our study – representing 58% of the trajectories in the data bank – shows a more complex journey. The first re-entextualization episode serves as the original source for the second re-entextualization episode, producing further modifications to the original text, and thus

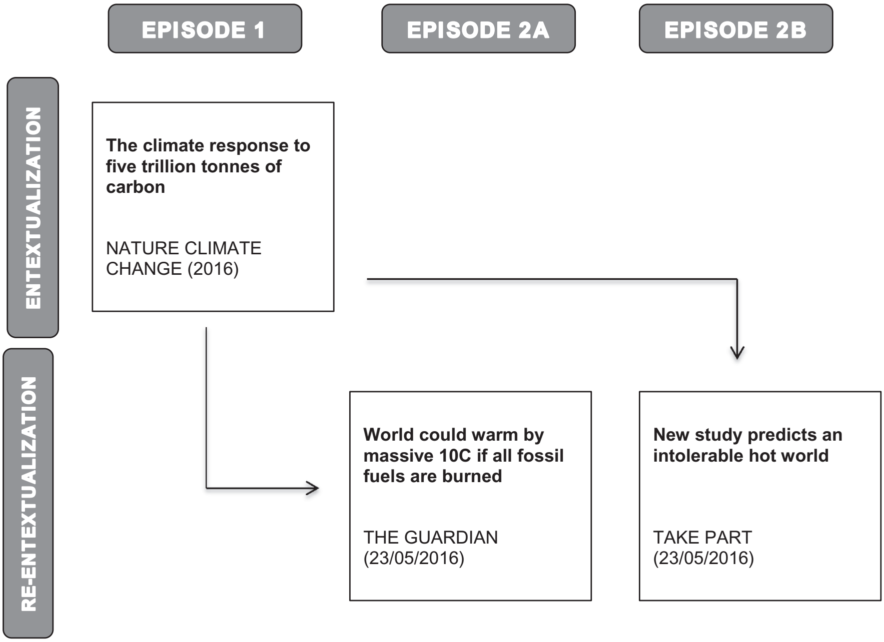


Figure 4: Trajectory pattern 2.

creating what we refer to as the 'broken telephone' effect. Significantly, in this trajectory pattern, the original text is not sought out for examination in the second re-entextualization. It is almost as if it had never existed. In only working with the first re-entextualization, something will inevitably be lost, hence the silences in the 'broken telephone' which, at the same time, allow for comprehensive transformations rather than a replication of the original story (Blommaert 2005).

As illustrated by Figure 5, Episode 1 (entextualized knowledge) published in the *Journal of Neuroscience* is the direct source for Episode 2 and the indirect source for Episode 3. The text in Episode 2 was published in the *New Scientist*, an English-language popular science magazine, and the text in Episode 3 appeared in *The Mail Online*. This particular scientific text has been re-entextualized for two completely different audiences, even if both publications aim at reaching 'the general public'. This points to the dangers and limitations of using monolithic terms such as 'the general public', which tends to mask important differences that characterize a particular type of audience, and indeed serves to perpetuate the deficit model of the public understanding of science in that the 'public' is positioned as the 'other' to scientific knowledge. This observation

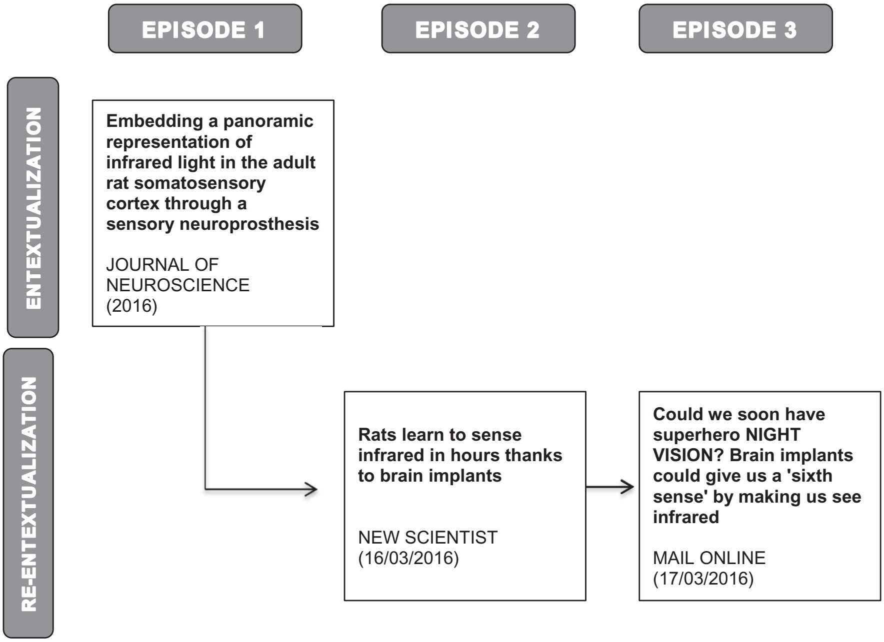


Figure 5: Trajectory pattern 3.

echoes previous arguments made for the need to move away from what Wynne (1982) has called deficit models (e. g. Myers 2003; Bucchi 2008; Simis et al. 2016; Gimenez et al. 2017).

These three patterns, which emerged from using ETEK, provide an overview of the typical journeys that scientific texts in our data go through when they are used for disseminating new knowledge. The journeys taken are more or less complex, although it cannot be assumed that the level of complexity necessarily correlates with greater distance between the contents of the episodes.

The examination of the patterns of text trajectory made possible by the application of our first heuristics presents a new empirical analysis of the processes involved in the (re)entextualization of scientific knowledge. By using ETEK we have, at the same time, managed to address questions about the patterns that entextualized scientific knowledge follows when it travels across time and space, and the best way to capture such patterns. These patterns, however, only show one level of analysis, which does not in itself provide access to the textual and rhetorical transformations that occur during these journeys. Such access is facilitated by TEREF, our second heuristic, as we discuss in the next section.

4.2 The rhetoric of re-entextualization

In this section we focus on the analysis of the textual and rhetorical transformations that scientific texts undergo when they travel across space and time following the trajectories discussed above. To this end, we applied TEREF to an instance of the third trajectory (see Figure 5) which was the most frequent trajectory in our bank of materials. Table 5 shows the results of the application of TEREF to selected excerpts from the three texts in the trajectory. As far as possible, the excerpts present information that is shared by the three episodes.

As seen from the table, Episode 1, which contains an artifact published in the *Journal of Neuroscience* on the malleability of sensory processing in adult mammals, shows the highest density of technical vocabulary and complex sentences with a high number of subordinated clauses, which characterizes texts that present highly complex and sophisticated ideas. Episode 2, published in a popular science magazine, on the other hand, shows a considerable number of non-technical and informative lexical items, short paragraphs with simple, short sentences and a low level of subordinated ideas and passives constructions, which seems to indicate that the texts in it are easier to read and understand than those in Episode 1. Episode 3 features an artifact published in the digital version of a British newspaper. It is worth noting that, as shown in Table 5, although the excerpts in Episode 3 contain non-technical and evocative language with short, simple sentences and one-sentence paragraphs, they appear to be almost as complex in expression and structure as those in Episode 2. This seems to suggest that, although the literature refers to simplification of scientific texts to make them more accessible to different audiences (Cook et al. 2004), there may be more at play here than just simplification.

The textual elements in Episode 3 in fact constitute a metadiscourse (a discussion about the experiment and its effects on human beings) rather than a re-contextualization of the discourse presented in the source episode (Episode 1), which affords the writer new forms and meanings to provide a particular reading on the experiment which was not part of the original text. This transformation and its new reading represent, at the same time, a new 'version of knowledge' that reaches the particular audience of Episode 3, thus emerging as an example of the social distribution of power and access.

The rhetorical level of analysis in TEREF also reveals some rather interesting observations in relation to the purposes, the attribution of authority and the visual elements of the artifacts in the episodes. As shown in Table 5, the purposes of the artifacts in the three episodes vary considerably. Whilst Episode 1 aims to provide a description of the experiment and the processes followed by the team of scientists, Episode 2 highlights the participants in the

Table 5: Application of TEREF on an example of trajectory pattern 3.

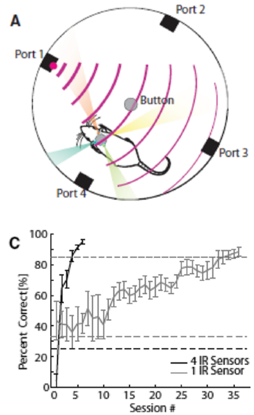
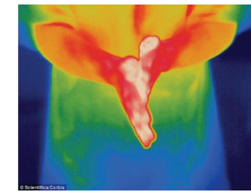
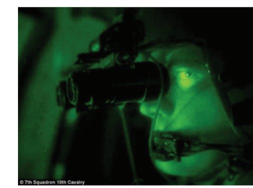
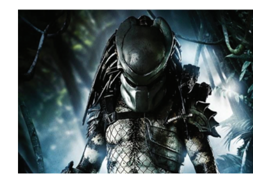
	Episode 1 ***Journal of Neuroscience***	**Episode 2** ***The New Scientist***	**Episode 3** ***Mail Online***
Biographical information	Hartmann, K., Thomson, E.E., Zea I., Yun R., Mullen P., Canarick J., Huh A., and Nicolelis M. A. (2016). *Journal of Neuroscience*, 36(8):2406–24.	Coghlan, A. (March 16, 2016). Rats learn to sense infrared in hours thanks to brain implants. *New Scientist*, 3066: 45. Available at https://www.newscientist.com/article/2080671-rats-learn-to-sense-infrared-in-hours-thanks-to-brain-implants/	Gray, R. (March 17, 2016). Could we soon have superhero NIGHT VISION? Brain implants could give us 'sixth sense' by making us see infrared. *Mail Online*. Available at http://www.dailymail.co.uk/sciencetech/article-3496895/Could-soon-superhero-NIGHT-VISION-Brain-implants-rats-sixth-sense-making-infrared.html
Title/Headline	**Embedding a panoramic representation of infrared light in the adult rat somatosensory cortex through a sensory neuroprosthesis**	**Rats learn to sense infrared in hours thanks to brain implants**	**Could we soon have superhero NIGHT VISION? Brain implants could give us a 'sixth sense' by making us see infrared**

Data (Excerpts)			
Introductory information	To work properly, cortical sensory neuroprosthetics will require that the adult brain be plastic enough to continuously process real-time streams of synthetic information sources, and then use the extracted information to guide appropriate behavioural responses. Classically, the highest levels of cortical plasticity have been observed during early development (Frost and Metin, 1985).	BRAINS get data about the world through senses – sight, hearing, taste, smell and touch. In a lab in North Carolina, a group of rats is getting an extra one. Thanks to implants in their brains, they have learned to sense and react to infrared light. The rats show the brain's ability to process unfamiliar data – an early step towards augmenting the human brain.	It has been put to good use by comic book superheroes and by alien predators hell-bent on wiping out mankind, but soon humans could also be able to see infrared light. Scientists have used brain implants to give rats a 'sixth-sense' that enables them to detect and react to the normally invisible light source. The research proves it is possible for the adult brain to adapt to new forms of input and opens up the possibility of enabling humans to gain an array of superhuman senses.
Methods and procedures	We implanted the electrodes bilaterally in S1 under full anesthesia. To initiate the anesthesia, rats were first put to sleep with isoflurane (Isothesia, Henry Schein Animal Health). For final anesthesia, we used a ketamine (Ketaset, Fort Dodge)-xylazine (AnaSed, Akorn Animal Health) anesthetic with 100 mg/kg ketamine and 0.06 mg/kg xylazine.	Miguel Nicolelis [Link to Nicolelis Lab webpage] of Duke University School of Medicine is leading the experiment. His team implanted four clusters of electrodes in the rats' barrel cortex – the part of the brain that handles whisker sensation (doi.org/bdb6) [Link to the journal's website]. Each cluster is connected to a sensor that converts infrared light into an electrical signal.	In the study, published in the Journal of Neuroscience, the scientists implanted four clusters of electrodes into a part of the brain responsible for whisker sensation in rats. Each cluster was connected to a sensor that converted infrared light into an electrical signal. Tests were used to show if the rats with the implants were able to detect the infrared light.

(*continued*)

Table 5: (*continued*)

	Episode 1 ***Journal of Neuroscience***	Episode 2 ***The New Scientist***	Episode 3 ***Mail Online***
Significance of the study	(Significance statement) Understanding the potential for plasticity in the adult brain is a key goal for basic neuroscience and modern rehabilitative medicine. Our study examines one dimension of this challenge: how malleable is sensory processing in adult mammals? We implemented a panoramic infrared (IR) sensory prosthetic system in rats; it consisted of four IR sensors equally spaced around the circumference of the head of the rat. Each sensor was coupled to a microstimulating electrode placed in the somatosensory cortex of the rat. Within days, rats learned to use the prosthesis to track down items associated with IR light in their environment. This is quite promising clinically, as the largest demand for sensory prosthetic devices is in adults whose brains are already fully developed.	"This is a truly remarkable demonstration of the plasticity of the mammalian brain," says Christopher James of the University of Warwick, UK. "The results show that nature has apparently designed the adult mammalian brain with the possibility of upgrades, and Nicolelis' team is leading the way showing how to do it," says Andrea Stocco of the University of Washington in Seattle. "Now there's no doubt that it's easy for the mammalian brain, even in adulthood, to adaptively use a novel, never-experienced sense, such as infrared," says Yuji Ikegaya of the University of Tokyo in Japan.	'This is quite promising clinically, as the largest demand for sensory prosthetic devices is in adults whose brains are already fully developed.' Professor Yuji Ikegaya, a neuroscientist at the University of Tokyo in Japan who was not involved in the research, told New Scientist: 'Now there's no doubt that it's easy for the mammalian brain, even in adulthood, to adaptively use a novel, never-experienced sense, such as infrared.'

Graphics			  
Levels of analysis			
1. Textual			
1.1 Lexis	Technical	Non-technical and informative	Non-technical and evocative
1.2 Structures	Varied length parapraphs; complex sentences; high level of subordinated ideas, high level of passives	Most short paragraphs; simple, short sentences; low level of subordinated ideas, low level of passives	Mostly one-sentence paragraphs, short, simple sentences; very low level of subordinated ideas, high level of passives

(*continued*)

Table 5: (*continued*)

	Episode 1 *Journal of Neuroscience*	Episode 2 *The New Scientist*	Episode 3 *Mail Online*
2. Rhetorical			
2.1 Focus	Experiment and processes	Participants and results	(assumed) Implications for readers
2.2 Significance	Contribute to the advancement of science ("modern rehabilitative Medicine")	Demonstration of the ability of the brain to adapt and upgrade	The ability of the brain to adapt and upgrade and what this could mean for people.
2.3 Attribution of authorship/authority	Direct ("we")	Partial ("his team")	Anonymised ("the scientists")
2.4 Visual purpose	Data display: used to visually represent data, the experiment, and processes	Representational: used to offer a comment on content (e. g. power of perception)	Expressive/Evocative: used to create an impact on the reader (infrared light, goggles for night vision, science fiction film – Predator)

experiment (rats in this case) and the results obtained, and Episode 3 focuses on the assumed implications of the experiments for readers. Whilst Episodes 2 and 3 report something (presumably) derived from the original, they have failed to provide their readers with the original data, although Episode 1 offers readers with a link to the original article. This signals issues of access and authority as we discuss in the next section.

While Episode 1 produces a small tile or tessera in the mosaic of scientific information, Episode 2 focuses on the bigger scientific conceit of discovery, and Episode 3 highlights the perceived extrapolated application. This trajectory, from the presentation of results to a consideration of their importance to the anticipation of their real-world applications, is part of the lifeworld of science, with knowledge, cultural value and practical use by the wider society being importantly different yet related elements (Gimenez et al. 2017).

The transformations in purposes are further supported by reference to the impact of the experiment presented in each artifact. In Episode 1, the impact is given by the contribution of the experiment and the team to the advancement of "modern rehabilitative medicine"; in Episode 2, the impact seems to lie in the ability of the brain to adapt and upgrade; whereas in Episode 3 it is also on the ability of the brain to adapt and upgrade, but with a slightly different angle given by what this could mean for humans. It is also worth noticing that references to the impact of the experiment in Episodes 2 and 3 also provide examples of text hybridization and Bakhtin's (1986) dialogism. As Table 5 shows, in these episodes, the discourse of science is blended with that of journalism by means of the interview quotes from other scientists. In Episode 3 this is further extended by quoting text from Episode 1, thus pointing to the fact that the episodes are not always clear-cut and sharply delineated as the figures above may appear to represent but nonetheless interconnected by intertextual and interdiscursive elements that create dialogues (even if sometimes competing) between them.

An analysis of the attribution of authorship and authority in the three episodes offers further support for the rhetorical changes in each text. Whilst in Episode 1 authorship and authority, for instance, are attributed in a direct way by the use of the personal pronoun "we", in Episode 2 this is realized indirectly by phrases such as "his team". In Episode 3, however, authorship and authority are largely anonymized by the use of phrases such as "the scientists" and "they". This indicates that the artifacts in the 3 episodes show a gradual distancing from authorship and authority by a process of 'othering' in order to be able to focus on other more material objects (in Episode 2) and the consequences for humans (in Episode 3), as shown in Table 5.

Rhetorical changes also surface by analyzing the functions of the graphs in the episodes. The graphs in Episode 1 are used to provide a visual representation of the textual information presented by the team of researchers, the experiment and the processes followed. Those in Episode 2, on the other hand, are representational in nature, mainly used to offer a comment on content (e. g. power of perception) – an example of visual metadiscourse – whereas those in Episode 3 are used to bring strong images, memories, or feelings to the readers (infrared lights and goggles for night vision in the science fiction film 'Predator').

This brings us to our main argument: the entextualization process followed by texts like these is not just a mere textual exercise but a manifestation of processes by which some elements in the original text are re-produced, others are re-interpreted and some others lost. These processes surface more clearly when texts are analyzed through the lens of a heuristic like TEREF, and thus questions around the specific textual and rhetorical transformations of knowledge which mask issues of power, authority and access can be addressed empirically. This is what we discuss in the next section.

4.3 Issues of social power, authority and access: Bringing it all together

As we have argued in a number of instances above, suggesting that the transformations undergone by scientific texts when they are re-entextualized in a variety of contexts are simply the result of textual changes in order to make them more accessible is not only naïve but also dangerous. This consideration helps to mask more important issues of power, authority and access whose textual manifestations are not always apparent, unless we analyze the trajectories of texts in a way that allows transformations (e. g. what is re-produced, re-interpreted, and lost) to surface more clearly.

As we have shown in Sections 4.1 and 4.2 above, the modifications that the same piece of scientific knowledge undergoes are far-reaching as they relate to content, focus and intent rather than just textual simplification. When put together to represent a trajectory, the excerpts provided in these sections, even if limited to stay within the word limit, show that as entextualized scientific knowledge travels across space and time it can acquire different focuses, purposes, forms and meanings. These transformations may very well be aligned with processes, interests, authorities, ideas, technologies and other objects that sociological analyses, although beyond the scope of this paper, could bring into view. As we can see, in Episode 3, for instance, by creating a metadiscourse the writer changed the purpose of the original discourse from a focus on the experiment and processes to the assumed implications for the readers, even when a few textual elements resemble those of the original. Even a cursory analysis of the changes in the title ("Could we soon have superhero NIGHT VISION?") and the visual elements in the episode (infrared light, goggles for night vision, science fiction film) suggests that re-entextualization goes beyond the textual by providing new forms and meanings in support of a preferred new reading for the re-entextualized discourse (Bloomaert 2005).

Issues of authority, what is re-produced or silenced, also play a crucial role when examining what causes these transformations. In the examples presented above, authorship is a point in question. In Episode 1, authorship is recognized and directly referenced as the scientists are the makers of the artifacts. However, this is not the case in Episode 3, where authorship is anonymized by referring to the producers of that particular piece of scientific knowledge as simply "the scientists". This helps to support the purpose of that particular act of re-entextualization by a process of distancing, and thus re-focusing the original discourse on the consequences of the experiment for humans.

Providing or denying access to resources – the original sources in this particular case – is also another type of transformation that seems to be part of the processes involved in the dissemination of scientific knowledge we have examined here. In the examples provided in Sections 4.1 and 4.2, access to resources that would help readers gain a more nuanced picture of the particular piece of knowledge being referred to gradually moves from 'providing' in Episode 1 to 'denying' in Episode 3. In Episode 3, references to the original source of information are so vague (e. g. "the research", "in the study", "published in the Journal of Neuroscience") that it would be rather difficult for non-scientists to trace what they are reading back to the original sources, leading them astray in the struggle over voice. This has significant implications for the potential to be able to assess any 'truth claims' being made and may, we speculate, have resulted from a number of issues including the perception of needs and interests, time pressures and limitations of space faced by the media, rather than possibly a deliberate intention to deny access. However, ideological influences may more or less consciously have an impact and afford opportunities in the moments of re-entextualization (Bernstein 1990). The effects on readers nonetheless are still the same.

As we have argued above, these issues of power, authority and access are not always readily available to analysts, let alone the public. It is thus, we would contend, necessary to pay closer attention to the processes of transformation to knowledge when mobilized across time and space, and to design new analytical tools like ETEK and TEREF that can help to capture the complexity of such processes. This could then inform the theory and the practice of scientific communication to different audiences.

5 Discussion: Theoretical implications and practical applications

The analytical considerations presented above have a number of implications for understanding the nature of communicating scientific knowledge to different audiences and some practical applications as well. The traditional approach to communicating scientific knowledge to non-scientists has had as a premise the need for educating an ignorant public. This approach, known as the deficit model, that still persists in scientific communication (Simis et al. 2016) despite having been severely criticized over the years (e. g. Wynne 1991; Myers 2003; Bucchi 2008; Luzón 2013), assumes that people have insufficient knowledge to be able to understand the basic principles of science, thus creating a dichotomous relationship between scientists and non-scientists. This is particularly manifested in the language many scientists have used regarding their efforts to communicate the results of their research where terms such as “experts” and “non-experts”, and “knowers” and “non-knowers” abound (Gimenez et al. 2017). The deficit model has also resulted in instances where the versions of scientific knowledge can be seriously transformed, especially when the science is moved away from the scientists, mostly by the media as the examples in the previous sections show. This has probably been the consequence of the void created by the lack of communication opportunities between scientists and non-scientists and the “overemphasis on disseminating scientific discoveries almost exclusively to the scientific community, via journals with high impact factors” (Gimenez et al. 2017: 44).

As we have argued elsewhere (Gimenez et al. 2017), more efforts to avoid deficit models and to bring together scientists and non-scientists with an interest in science could help to minimize distortions and misinformation. This would provide scientists with an opportunity to share and explain their work and different audiences to ask questions directly from the source of scientific knowledge, thus helping to reduce ‘the broken telephone effect’. This type of social collaboration could help enhance public participation, understanding and engagement with science and, at the same time, help scientists develop communication skills for disseminating new knowledge to non-specialist audiences.

From a pedagogical perspective, analysis of the trajectories of scientific knowledge like the one we have offered in this article could help inform research-supported pedagogies for teaching science, technology, engineering and mathematics (STEM) students the communication skills they will need to interact with a multiplicity of audiences in their future professional life (Gimenez and Roque Gutierrez 2016). By raising their awareness as to the need for both such skills and social collaboration with non-scientists, future scientists would hopefully be approaching communication with different audiences from a collaborative rather than a deficit perspective. In this way, not only scientists, but also academics, the media and the public would contribute to making scientific knowledge "a fundamental part of culture and society at large" (Gimenez et al. 2017: 45).

6 Conclusions

In this paper we have examined the textual and rhetorical transformations that entextualized scientific knowledge undergoes when it is re-entextualized in a variety of contexts as evidenced in the trajectories of a number of science-related texts.

Considering some of the key existing literature on the analysis of multiple instances of knowledge dissemination, we have managed to show how our theoretical considerations and analytical tools can be applied to other contexts like the re-entextualization of scientific texts which, despite a few notable exceptions (e. g. Myers 2003; Luzón 2013), has received little research attention.

In a similar vein, the two innovative heuristics we have described here provide a new analytical lens for similar work in the field. These heuristics rigorously and systematically help to describe processes in knowledge entextualization and as such could be used in future research in the field of scientific discourse and knowledge dissemination. In recent years efforts have been made to provide scientists with opportunities to write for non-academic audiences. Future research could thus look at how scientists write for non-academic sources, and draw comparisons of entextualized trajectories of knowledge written by scientists and non-scientists for the wider public. Such work could examine questions such as: How do scientists overcome the gap between scientific and everyday language when constructing such texts? Do they consider themselves to be successfully acquiring the writing practices required? Do they feel their writing is being correctly interpreted? Do they view such practices as communication in lay terms to be transformative?

Finally, the data and the analyses presented in this paper make a contribution to existing views and approaches to the dissemination of new scientific knowledge as well as an opportunity for readers to reflect upon the practices of communicating knowledge to multiple audiences. As the literature has shown, there has been a marked tendency for communication between scientists and non-scientist to be heavily influenced by the deficit model (Simis et al. 2016). As we have argued here and elsewhere, an approach involving close collaboration between these groups would help to avoid the distortions experienced by scientific knowledge when it travels across different entextualisation contexts. By the same token, such collaborations would have enormous benefits not only for the scientific community but for society at large.

Appendix

Pattern 1

Emspak, Jesse. 11 May 2016. What we would actually do to stop a 'doomsday' asteroid. *BBC Fut*ure. http://www.bbc.com/future/story/20160510-what-we-would-actually-do-to-stop-a-doomsday-asteroid (accessed 9 October 2017).

Zhang, Qicheng, Kevin J. Walsh, Carl Melis, Gary B. Hughes, & Philip Lubin. 2015. Orbital simulations for directed energy deflection of near-earth asteroids. *Procedia Engineering*, 103. 671–678.

Pattern 2

Carrington, Damian. 23 May 2016. World could warm by massive 10C if all fossil fuels are burned. *The Guardian*. https://www.theguardian.com/environment/2016/may/23/world-could-warm-by-massive-10c-if-all-fossil-fuels-are-burned (accessed 9 October 2017).

Gertz, Emily J. 23 May 2016. New study predicts an intolerably hot world. *TakePart*. http://www.takepart.com/article/2016/05/23/high-heat-global-warming-fossil-fuel-renewable-energy (accessed 9 October 2017).

Tokarska, Katarzyna B., Nathan P. Gillett, Andrew J. Weaver, Vivek K. Arora, & Michael Eby. 2016. The climate response to five trillion tonnes of carbon. *Nature Climate Change*, 6(9). 851–855.

Pattern 3

Coghlan, Andy. 16 March 2016. Rats learn to sense infrared in hours thanks to brain implants. *The New Scientist*, 3066, 45. https://www.newscientist.com/article/2080671-rats-learn-to-sense-infrared-in-hours-thanks-to-brain-implants/ (accessed 9 October 2017).

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