

Use of Narrative in Science Communication

Abstract

The research paper analyzed storytelling devices employed by five most credible and popular science journals to understand how the narrative framework can be integrated into science communication. Through the content analysis, application of the classical narrative framework to the articles, and organization of the information, the research helped to reveal original literary tools and patterns that can be employed in to create better stories. The insights from the research can be used by other science publications to develop more narratives in the future.

1. Introduction

Sciences are often seen as something difficult and boring. Even though it is not true, it is the reputation that many natural sciences like chemistry, physics, and biology have. Those subjects seem distant from daily matters, which makes it hard to find them practical applications. The negative reputation has primarily derived from the way media and institutions communicate scientific information to the public. Usually, sciences publications are associated with formal education or sensationalists titles in the press. In the result of those often conflicting presentations, people feel detached from scientific discoveries and think of well-established scientific facts as of “perspectives.” But if appropriately communicated, sciences can find practical applications in everyday life of people that may significantly improve their well-being. The information they provide can help solve problems, increase efficiency, and protect from harmful influences of pseudoscience.

Sciences do not exist in a vacuum - they tell something about the world and attempt to understand it. Having proper communication of information would imply that more people would know how to make more educated choices and have a critical approach to the information they receive from the media. That is the main task of science communication media outlets like newspapers, magazines, movies, and non-fiction literature. But since many scientific concepts are complex, they demand attention, engagement, and understanding before they can become practically useful. That makes communication of sciences challenging. One of the ways to draw people in and efficiently deliver information can be through storytelling. Stories are known for the ability to draw in and keep the attention. Their ability to be relatable, memorable and accessible has been efficiently utilized by many business and politicians. Though the positive influence of storytelling has been proven, there are currently no effective frameworks and guidelines that can help writers create compelling and effective stories that accurately describe scientific concepts. Narrative storytelling is still not a genre commonly utilised by science communicators, and many of the writers are reluctant to start employing narrative tools when writing about science.

The connection between storytelling and science communication based on the best available practices is what has been analyzed in this research. The study tried to understand how storytelling is currently used in science communication and how future communicators can utilize storytelling to create better stories relying on the current practices. The conclusions of this study were based on the content research of the reputable science publications and the tropes they have used in their articles. During the process of research, I have collected a sample of 40 articles from five different publication, and categorized findings by answering questions about the articles. The information gained from the analysis has helped me to make valid conclusions

about ways in which narrative tools are currently used to create compelling and how those observations can be used to create a factually accurate content in the future. The study is mainly focused on current practices of the storytelling in science communication, how is it done, and what were the preconditions for favoring one way of storytelling over another from one journal from another.

2. Literature Review

Sciences communication has an important role in the public education, but because of sciences are highly-technical the process of science communication is challenging. For that reason, the field of science communication has been subjected to criticism. The discipline has defined standards, but as the research has indicated, those standards do not have a proper practical application. The practical use of science communication research is what I will explore in my later work. To approach the subject, I need to define what science communication is, why it is necessary and what are the benefits of science popularisation. Then, I will analyze what has been done in the field and overview common criticisms science communication field faces right now. After that I will look at specific examples that utilize power of narrative communication.

Science communication is not easy to define, and even representatives of the field struggle to explain the meaning of the concept conclusively. In the historical overview of science communication and channels of communication, Robert Lucky showed that the confusion exists, because throughout last couple of centuries science communication has experienced a rapid transformation. The field has changed its purpose from 'only communicate a piece of knowledge from one place to another' to 'educating people of different backgrounds about the scientific achievements in a compelling manner.' (Lucky, 2000) Science communication is a useful

education tool because it helps to break down complicated matters into comprehensible ideas and has been used by media and different institutions. One of the benefits of studying science communication has been pointed out by Baruch Fischhoff and Dietram A. Scheufele in their article 'The Science of Science Communication II.' They state that adequately communicated knowledge can arm people with tools that can help them in their everyday life. They acknowledge that science communication can benefit economies and countries, by cutting down on economic costs of improperly communicated science and pseudoscience. (Fischhoff, Scheufele, 2014). The other benefit of communicating sciences is that it not only presents current knowledge in the field but helps to advance it forward. When communication channels improve, and communication methods became more compelling, sciences start advancing at a higher pace. Thus, developing science communication and using more tools to make scientific knowledge easier to grasp for the public means to engage more people in sciences, increasing the speed of their development. (Lucky, 2000)

Science communication has been historically done from scientists to other scientists or the narrow public. However, with the rise of clickbait journalism, it can be done by everyone. Considering that public's knowledge about sciences is not as high, the accuracy of scientific materials available for circulation is doubtful. For that reason, in the recent years, many analytical pieces have been published that aimed to redefine standards for scientific communications. According to Prajwal Kulkarni piece 'Rethinking "Science" Communication,' scientist should not 'generalise' all sciences, presenting different field as one and equating them to the same standard. All sciences are not similar, they serve different purposes and use different methodologies. Science communication mission should be to specify the methods and difference between fields, so that audience will have enough knowledge to make rational conclusions about

the validity of the information presented in the future. (Kulkarani, 2013) The other issue with science communication is that by trying to appeal to everyone, it is usually oversimplified to the point when stated 'facts' lose their validity. To serve a right purpose scientists should not entertain, but look for ways to engage readers with the content of complicated matters enough for them to grasp the material. Scientific knowledge, as stated by Trevor Quirk in *The Problem With Science Writing*, can be hard, and by making it look like it is not, one puts the accuracy of the information and thus its usefulness at risk. (Quirk, 2016) To make the content more engaging science communicators do not need to simplify the material. They should strive to use the knowledge the human society has acquired from fields of psychology, literature, sociology, and history in the creation of new pieces of content. (Fischhoff, Scheufele, 2014)

The narrative framework - using storytelling to break down complicated subject - is considered to be a useful tool when analyzing science communication works. It has a high engagement value, and by understanding how narrative storytelling affects learning and memory, science communicators can create content that is both interesting and factually accurate. (Downs, 2014). When the audience is interested enough to follow the story, even the most complicated matters can be communicated with ease. The study that analyzed 'The Impact of Science Fiction Film on Student Understanding of Science' also tested the hypothesis. Researchers examined how university students would react to the information presented in the factually accurate fictional movie story. Scientists found that more students were referencing the movie as a source of their knowledge in the test. The study found that students recalled information presented in the movie easier than the information presented in the textbook. (Barnett, Wagner, Gatling, Anderson, Houle, Kafka, 2006) The idea applies not only to the content consumed but also to the content produced. Dr. Djerassi has conducted an experimental class in Harvard's medical

school to test the point. Throughout the class, he asked his students to write stories about ethical problems in medicine. The final test results and students engage in the course, indicated that using fictional frameworks when explaining scientific concepts can be an effective way of learning and understanding the information. (Djerassi, 1998).

Even though the potential value of fictional storytelling in science communication is acknowledged, elements they use to make stories engaging while keeping the accuracy of the presented material has not been studied as well. The science communication is the process which has peculiarities, which have been attempted to be identified in this research. The research tried to look whether differences in telling the stories is connected to the way communicators structure their work, use language, or graphics to make their point clear. In the research I looked at popular science communication texts, articles, analysed their backgrounds and attempted to understand how they used classical three-act narrative structure with a defined hero, conflict, and resolution to tell a scientific story.

3. Research Question

Science communication researchers have established what science communication should do.

However, the research in the field lacks an in-depth analysis of scientific contents.

Understanding that storytelling has repeatedly been used by other fields to enhance understanding of concepts and increase recall of the material, storytelling in science communication can serve an important purpose. It can address common problems of presenting complex scientific ideas, without oversimplifying them or sacrificing accuracy of the information. The main question that has directed my research is: *How are storytelling elements used in narrative scientific content?*

4. Methodology

To form conclusions and answer the research questions it was necessary to conduct a content analysis of the science communication pieces. The research consisted of the three steps that helped to select, code, and analyze the articles.

1. Selecting Journals and Articles

To make a valid conclusion about the state of storytelling in the science communication right now, it was necessary to select a representative sample of articles from different publications for the analysis. The length of articles, their validity, diversity, and what subjects they covered were the main criteria based on which the selection process has occurred. To perform the research, I have selected five publications and then using different search markers, selected eight pieces from each journal. In the result, the research has been performed on 40 articles.

To choose relevant publications I took into consideration three different metrics: credibility, mission statements of the website, and readership of the audience. To ensure that the magazines were credible and the information they presented had a high standard of accuracy, I have realized on lists posted by Media-Bias Check and Journal Citation Reports. (Clarivate Analytics, 2017) All of the publications scored ‘very high’ on factual accuracy, and the academic journals selected for the analysis had the highest JCR scores. After the initial research was performed and ten journals have been selected, I have also performed background researchers, to ensure that the reputation of the journals was high. To ensure that the journals had a mission of ‘communicating sciences to a wider audience’ the analysis of the journal’s mission statements also has been performed. Then I looked into the readership of journals their circulation and

selected narrowed the list down to the journals that had a wider audience. The final list of journals consisted of the following journals: Nautilus, Scientific American, Science, Nature, and National Geographic.

To ensure that I would have a representative sample that would reflect the main position of magazines about science communication, I selected eight articles from the selected publications. The number has allowed me to take a closer look at the articles, while still making sure that sample would reflect the journal's attitude towards storytelling. When selecting articles from each publication, I set prior criteria that helped to narrow down the search. The main purpose of the criteria was the diversification of the content pieces selected for the analysis. Following criteria were set:

- Articles should have been published between 2013 - 2018.
- Articles should be from at least four different disciplines.
- The article should belong to one of the following science disciplines: Computer Science, Physics, Biology, Math, Astronomy, Chemistry, Medicine.
- All articles from the same publication should have different authors.

2. Defining Narrative Frameworks

Since there are many definitions and forms of 'narratives,' it was important to define what the word is going to mean in the context of the conducted research. For this research, I decided to use a framework established by a science communicator Julie S. Downs. In her article about the perspectives of using narratives structures for communicating sciences, she identified 'narrative' as a story which should contain three key elements:

- A character

- A conflict
- Resolution of the conflict

Even though it is one of the most simplified models, also called three-act narrative structure, the framework offered enough flexibility considering, that the research was conducted using articles from magazines. (Downs, 2014) Since scientific narratives should not only entertain but also educate, the narrative itself should not have replaced scientific concepts, but only enhanced them. For that reason, the three-act narrative framework seemed the most appropriate.

To identify the presence of the narrative structure in the articles I used following markers.

Words that helped to identify the presence of a character

- He, she, names, hero, writer, scientist, his, her, professionals, researchers

Words that helped to identify the presence of a conflict:

- Faced, struggled, feared, challenged, wanted, striving to

Words that helped to identify the presence of a resolution:

- Solved, rewarded, resolved, resulted, understood, achieved

3. Analysing the Articles

When reading each piece, I answered following questions:

- Who/What is the main character?
- What is the conflict?
- How is the conflict resolved?

- What concepts/scientific ideas the articles describes?

- What discipline the does article belong to?
- What literary devices the article uses in its storytelling?
- How can I the main storyline of the article in a sentence?
- How easy was it to read and understand the article?

5. Content Analysis

5.1. Scientific Journals

Nautilus

About Nautilus

Nautilus is a science magazine that was launched in 2013 with the support of grants from the John Templeton Foundation, the Simons Foundation, and the Howard Hughes Medical Institute. The main message of the publication is 'Science connected.' The mission of the magazine is to connect science with humanitarian subjects. It explores scientific ideas from perspectives of culture, history and philosophy using storytelling. The articles published in the magazine resemble essays more than they do news stories. They are analytical, insightful, and they frequently employ the storytelling structure. Nautilus is advocating for an original kind of science journalism, that focuses on the exploration of scientific subjects and related them with everyday. By creating an unusual for science journalism structure the magazines have avoided getting into the trap of sensationalistic journalism. (Overbye, 2013)

The website is broken into issues and subjects. Each issue of the magazine revolves around a central theme like Self, Cosmos, or Luck. A new issue is published in the digital

version once a month. In the articles, writers connect the big idea of an issue with concepts from physics, archeology, biology, chemistry, mathematics and many more. It is divided into four or five chapters with around three to four articles in each. The Prime users of the website can have unlimited access to all stories at the beginning of the month. The regular readers get one chapter a week on Thursday.

Besides the main issue, Nautilus also has a blog called 'Facts So Romantic' which is updated on a near-daily basis. The blog is more news-oriented and usually has a format of commentary on a cultural and news-related idea. The magazine also has a section with articles from other popular culture and science publications (MIT TechReview, Quanta) and occasionally posts animated science videos. The landing page also issues the podcast series of the magazine and the best articles for their readers. Outside of delivering interesting stories that adhere to scientific principles, the magazine often works with other organization on projects that promote science communication like 'Think Like a Scientist' made in collaboration with the Howard Hughes Medical Institute.

Regular readers and visitors can read for free seven articles every month, To read more and have unlimited access to the previously published media content the readers should either become Nautilus Prime members or have a subscription to the Print version of the magazine. The physical copy of Nautilus comes out six-time every year. The print version is illustrated with original works commissioned by the magazine and printed on a high-quality paper. The magazine aims to make each issue of the magazine 'collectible.'

Nautilus scores 'very-high' on its validity and credibility and is widely respected and accepted among the scientific community for its high publishing standards. Even though it is a young magazine, it has already won many awards for its journalistic, publishing, and design like

the Library Journal's Ten Best New Magazines Launched in 2013 and two National Magazine Awards for General Excellence (Literature, Science and Politics Magazines) and Best Website in 2015. (Bilton, 2016)

Articles are written by famous science writers, journalists, and scientists. Pieces often have a long-read format. They are thoughtful, scientifically valid, analytical and often have a storytelling structure. They try to look at the topic from multiple perspectives. The thoroughness with which publication is approaching each issue makes for long production time. Preparation of one issue can take up to six months from of an idea-pitch to its publishing.

Readers can access the digital version for \$2.99 for an issue, or pay around \$29 for a digital and print yearly subscription. There are other subscription options available, with a lifetime subscription to the digital version, which costs \$99.

The website has 6.3 unique visitors and the combined paid circulation and through bookstores and newsstands circulation of the magazine is 12,000. The magazine is mainly oriented towards younger readers, with over a half of the print magazine's readership being under 40. Nearly 90% of them have a college degree, 40% have master's' degrees, and around 20% own a Ph.D. (Nautilus, 2017) To keep the readership of that diverse nature interested, Nautilus publishes articles that are both factual and entertaining.

The primary source of revenue of the company comes from its Prime Subscriptions and grants from scientific foundations. But lack of funding has led to a controversy that happened in 2017 because of Nautilus ran out of money and did not pay writers for the articles it has commissioned. (Bilton, 2016) The publishing board of the magazine has publicly admitted its fault, and paid compensations to the writers, but the lack of money is still an ongoing problem that the paper is trying to resolve. (Schulson & Raeburn, 2017) Nonetheless, the paper has a

loyal readership and following. The magazine is one of the leading publication in the field of science communication.

Analysis of Articles from Nautilus

The unique format of the journal allowed for the creation of insightful and thoughtful articles. For that reason, classical storytelling structure is prevailing among the types of articles published in the magazine.

Typically, even though articles describe many concepts from different fields, each article could have been attributed to one scientific discipline. Stories usually revolve around an idea or a scientist. Three out of eight articles selected for the content analysis revolved around an idea. In the article 'Quantum Mechanics Is Putting Human Identity on Trial' the writer described concepts of quantum theory and elementary particles. (Gefter, 2015) In the 'Encounters with the Posthuman,' the writer wrote about achromatopsia, cyborgs, and transhumanism. (Davies, 2015) And in the 'What Pigeons Teach Us About Love,' the focus of the article was evolutionary biology and the chemistry of love. (Keim, 2016) Even though those articles described different subjects, the way they structured and illustrate concepts is similar.

The conflict for each subject was different, but usually, the characters dealt with a problem, the solution to which could have been found by understanding the science behind the problem or technologies. In the idea-centered articles from Nautilus, conflict was hero's desire to find a solution to a problem. In the 'Encounters with the Posthuman' Neil Harbisson has achromatopsia, a rare condition that does not allow him to distinguish colors. He turns to science in order to find a way to start experiencing colors and finds a solution to his problem in the transhumanism. That is how conflict is set and resolved in the story. (Davies, 2015) In the

‘Quantum Mechanics Is Putting Human Identity on Trial’ the story is the concept of quantum mechanics itself. In the piece, storytelling is used to simplify the idea through visualization of the behaviors of elementary particles, using settings of human court trial. The conflict and revolution in this story are the scientific theory itself. (Gefter, 2015) The story makes up a conflict, creates fictional narrative and characters in order to explain a difficult idea.

The last article that describes an idea is ‘What Pigeons Teach Us About Love.’ The story revolves around pigeons and attempts to answer whether animals have the same complexity of feeling or not. The birds that fall in love are the main heroes of the story, the validity of their feelings in comparison with human ones is the conflict. The scientific analysis of the argument is the resolution of the problem. (Keim, 2016)

Besides having the story revolve around a concept, the articles from Nautilus also told stories of scientists. The biographical stories were told from the perspective of scientists and detailed on the role of the scientist in establishing a new concept. In the ‘How Information Got Re-Invented,’ ‘Math’s Beautiful Monsters.’ ‘The Man Who Tried to Redeem the World with Logic,’ and ‘The Astrophysicists Who Faked It’ scientist and their scientific achievements were at the heart of the storytelling. Sometimes, the conflict in those stories was scientists struggle to be understood, like Karl Weierstrass struggle in the ‘Math’s Beautiful Monsters’ and Walter Pitts efforts ‘The Man Who Tried to Redeem the World with Logic.’ (Kucharski, 2014)(Gefter, 2015) In other cases, the scientists desire to formulate a theory, like in the case of Claude Shannon from ‘How Information Got Re-Invented,’ and Jonah Kanner from ‘The Astrophysicists Who Faked It’ was the main conflict of the story. (Goodman, 2017) (Gefter, 2015) The resolutions those stories matched the conflict, and the scientists who were looking for recognition found it, and the scientist that wanted to formulate theories developed them.

Overall, stories in Nautilus resembled fictional narratives. The main purpose of the articles was to tell a story using an understandable language, so that the scientific ideas and concepts could have been fully understood by the reader. Unlike other publications, articles in Nautilus described scientific ideas in more details, and did their best to incorporate those ideas into the plot of the story they presented. They used many literary tools and made an effort to educate the reader even about matters that should have been challenging otherwise.

Scientific American

About Scientific American

Scientific American is the world's leading magazine about scientific discoveries and technological innovations targeted to a more general public. It presents itself as a publication that the readers can turn to for a deeper understanding of how science and technology can influence human affairs and illuminate the natural world. The main audience is people who are not scientists and just enjoy reading about sciences. (Scientific American, n.d.) It has both printed and digital versions. The two publications have slightly different focus, with print publication being more interested in feature stories and timeless, more storytelling pieces, and the digital version mainly reporting on the news in the field of science.

Scientific American is the oldest continuously published monthly magazine in the United States. It was founded in 1845 by an inventor Rufus M. Porter. It started out as political commentary journal and involved in to a popular science publication under the governance of Orson Desaix Munn III and kept the style ever since. (Santora, 2005) From 2008, Scientific American became part of Nature Publishing Group, the company that owns Nature - one of the leading science journals in the industry that I have also analyzed for my research. Scientific

American is on the frontiers of science communication and has played an important role in the political discussions and disputes and is often seen by the public as a more liberal publication.

(ScientificAmerican.com, n.d.)

Scientific American is news-oriented and reports on the latest conversations, discussions, and researchers in sciences. The structure of the website compliments that interest in the news stories. First ten stories, published at the top of the main page, are the news stories. The section gets updated at least once in every three hours. The next section that is featured on the landing page is the magazine's most popular stories. Stories that make it to the most-popular section are usually articles published within ten days and often cover stories that are more humanistic, meaning they cover subjects like health, psychology, and sociology.

The next section on the main page is the current issue section, which is locked for the visitors of the website that are not subscribed to the magazine. The reader can subscribe to its digital version for \$39.99 for four years, or its print versions for \$34.99 for one year; there is also a \$99 package that combines one year of the print version with four years of the digital version. The magazine also can create a sponsored content for organizations that want to be featured in the magazine. The stories are written by a special editorial board and appear on the main page for a longer period. For the partners the magazine emphasizes its credibility, making it the selling point of the journal. (Scientific American, n.d.)

After the subscription offerings there are featured other longer content pieces produced by the magazine under the headline 'Special Reports.' Then there are separate sections for 'Infographics,' 'Videos,' and 'Podcasts.' The main navigation bar of the website has following subsections - Sciences (which collects all the news stories related to the natural sciences), Mind, Health, Tech, Sustainability, Education, and Blog. The selection of subjects is different from

other science publications like Nautilus, Science and Nature, which again shows that the magazine gravitates towards the subjects that are connected to people's life and will possibly have a higher readership. Since Scientific American mainly writes about news, the articles are often short. They often use stock images and employ a journalistic news reporting formats. The longer more analytical, come out once a month or get published in the printed issue, which cannot be accessed without a subscription. All that also means that the magazine does not prioritize storytelling over other types of communication, and publishes articles that have a compelling stories not as often as some other science publications, selected for the analysis.

Analysis of Articles from Scientific American

The content of articles is dictated by the structure of the magazine. Article were short and the concepts were explained briefly, with references to other articles in the magazine. The titles were catchy and appealed to the viral nature of the social media websites. The language used in the publication is less poetic and literary than the one used in other publications chosen for the research. The articles are journalistic, with expectable flow and structure. Usually, they could have been attributed to one field of sciences. The writers connected that field of study with a topic from news or with popular messages. The articles were mainly focused on the observations rather than science behind those ideas. As was mentioned above, stories were human-centered and often connected or explained why the idea can be considered relevant to other people.

Since Scientific American is centered around news stories, finding storytelling pieces that had a familiar storytelling structure with character, conflict, and resolution was more difficult than with some other magazines. Counterintuitively, the articles most mass oriented journal from the sample were more difficult to read and understand. The storytelling format was slightly more

common among articles that either reported on buzz topics in the field of science or described a research process from a perspective of a scientist. Each of those two ways of narration had its own specifications.

One of the stories, that centered around a buzz topic was a story about Olympic snowboarders and their tricks, analyzed from the perspective of physics. The story of ‘Olympic Big Air Snowboarders Use Physics to Their Advantage’ is set before the US’s Winter Olympics team debut in Pyeongchang, South Korea in 2018. It detailed on how the athletes use concepts from physics such as angular momentum, equivalent fall height, and engineering of snowboarding fields in their drives. The article used snowboarders as heroes and set the challenge of the performance as a conflict. The resolution was the practical application of the scientific knowledge. (Skibba, 2018) The article used storytelling structure to set an interesting story for readers that might have not had interest in sciences but would have found the article about sports entertaining. The catchy title and as storytelling structure helped to make it appealing to the mass readership.

Scientific American employed similar model of connecting the news stories with science in some of its other storytelling articles. In the ‘A Private Place Where HIV, Zika and Ebola Hide’, ‘Brain Hackers Seeking Peak Performance Use Risky Chemical Cocktails’, and ‘Intelligent Aliens May Know about Us Well before We Find Out about Them’ the main characters and their experience with a something that had a scientific value were in the center of the storytelling. (Shraddha Chakradhar, 2018; Glionna, 2017; Mirsky, 2018) The conflict in those stories revolved around an idea, or a person was not related to sciences. Heroes in those articles wanted to improve human performance, find alien life or explain how an HIV positive person can go through ‘Gender Reassignment Surgery.’ In those articles, questioning capabilities

of sciences and its potential were the conflict. The resolutions was either not given or only speculated upon, since the problems they articles presented are ongoing with no clear yes or no solutions available yet. The stories were the main focus of the pieces through the entire articles and were only occasionally interrupted to present a scientific concept of theory in more details. The articles were usually connected to a wider range of domains and posed ethical and philosophical questions.

The other type of articles that used storytelling structures were articles that described research processes from the perspective of scientists. In the ‘280-Million-Year-Old Fossil Forest Discovered in Antarctica’, ‘My Year on "Mars"’ and ‘The Neutrino Puzzle’ main heroes were scientists. The conflict was the research itself and in difficulties scientist face as researchers. In the ‘280-Million-Year-Old Fossil Forest Discovered in Antarctica,’ the main conflict was the expedition to Antarctica in search of evidence of forests on the far land. (Pappas, 2017) In the ‘My Year on "Mars"’ the field expedition to a simulated Mars environment and the challenges of the experiment were at the heart of the problem. (Heinicke, 2018) In the ‘The Neutrino Puzzle’ the journalist’s visit to Clara visit the Dune Collider is the setting of the fictional conflict. (Moskowitz, 2017) Even though all of those stories presented different ideas they detailed on the research process. A story-like structure was used to report on what scientist are working on right now, what has been discovered and what they hope to learn in the future. The resolution often consisted of analysis of the current situation, evaluation of it, and speculations about future possibilities.

Overall articles in the Scientific American focused more of news in the field of sciences, reporting on popular ideas, and writing feature articles that connected sciences to everyday life.

The focus on the terminology heavy science was minimal and the storytelling was used to connect the scientific ideas with people.

Science

About Science

Unlike previous publications, science is a peer-reviewed academic journal that not only publishes articles for a general audience but also publishes scientific studies and research papers. The main focus of the journal is publication and circulation of original research papers and research reviews. But the website version and the print versions also report on science in the appealing to the mass audience way. It covers all scientific disciplines and is considered to be one of the most highly cited and credible scientific journals in the field. Many of other publications selected for this research use the information originally published in Science as their primary source material. All of that makes Science one of the most competitive journals in the industry, with the publication rate only 7%. The journal has around 130,000 subscribers to its print version, and the overall readership of the journal, including institutional subscriptions and people who have access to its digital version, is more than 570,400. (AAAS, 2015)

The first publication dates back to 1880. The journal was founded by journalist John Michels and financially supported by Thomas Edison and Alexander Bell. After facing financial difficulties in 1900, it was bought by American Association for the Advancement of Science (AAAS) and gained back its popularity by becoming the official journal of the association. Many notable scientists like Albert Einstein and Edwin Hubble have published their original breakthrough researchers and discovering in the journals. (AAAS, 2015) There Science has many branches that focus on coverage of research from different fields of study like Science

Translational Medicine, Science Signaling, Science Advances, and Science Robotics, and Science Immunology.

The first section on the landing page of the website consists of the six articles selected by the editorial team. Even from the website, it is clear that the magazine priority is scientific research because many of the selected articles in that opening section are related to the current research. It favors those articles over news and storytelling stories. The next section is news column which is broken down into two - Latest News and Career News. The latest news section is updated daily with around 7 to 10 stories a day. The topics of stories range from public policy breakdowns to research summaries. The news articles on the landing page had only titles and small photos and illustration. Since there are no leads, or summaries when the reader first sees the articles their titles are often long and descriptive. The career section is oriented towards the main demographic of the magazine - scientist and academic research papers with overviews of opportunities, career, and research tips.

The two sections that follow the main section are related to the research currently published in the journal and 'sister' journals of Science. The sections are titled First Released Science and Journals. Title of those articles are even longer than the ones in the news section and unlike the news stories use scientific jargon. Each issue of the journal has around 40 - 50 articles. A new issue of the main Science journal comes out once a week. Some of the articles from the journal are open to the public. Those articles are usually editorial, public health, and opinion pieces. All research can be accessed by the public within a year after the publication. However, the majority of research papers is available only for prime subscribers and owners of the physical copies. The journal is published mainly for people who have a professional interest in sciences or more scientifically literate audience than previously analyzed magazines.

The subscription to the paper is not heavily promoted on the website. To subscribe to the journal you need to click on 'become a member' button on the top of the screen. No other pop-ups and promotion appear on the website. By subscribing to the paper for a year, you also become a member of nonprofit American Association for the Advancement of Science (AAAS). The digital or print versions of the journal are available. The rates of subscription differ for Regular scientists, Postdocs, Student, Teacher, Retired, and Science Advocate. The articles can also be accessed through institutional domains. The cost of a regular digital copy is \$80 and the print version \$109. Other members can get the journal at a reduced price. The price policy also reveals the Science's advocacy for the availability of free of charge access to the journal.

After the news and recent research section, the website has a Featured Videos, Insights, which features the most important papers published in the journal, topics, popular articles, and editorial peaks, podcasts of the journal and 'How To Get Publish' instructions. The Topics section breaks the journal into ideas that get the most attention from the researchers like Cancer, Ebola, CRISPR, energy, etc..

Analysis of Articles from Science

Since Science is one of the most reputable journals with rigorous publication requirements and for that reason the quality of articles published in the magazine is also high. The diversity of authors also reflects on the diversity of topics covered in the magazine. The storytelling perspectives were interesting. Some kind of storytelling with a historical overview and mentioning of key players in the industry was present in many articles both in the news section and regular publication of the journal. The language was clear and simple. In the news stories,

the scientific jargon was reduced to a minimum. The topics covered in the magazine were often specific.

Even though articles in the Science articles touched upon more complicated subjects than Nautilus and Scientific America, because of the language used in the publication, it was easy to read them. The magazine used illustrations when presenting subjects that would have been impossible to write about without using a complicated jargon. In general, the news and available for the public stories for the journal prioritize conveying a story over creating viral articles, with quality analysis of subjects and quality descriptions of scientific concepts. They told stories behind the research and presented a perspective that is often missed in the regular research papers.

The articles selected for the research can be thematically divided into two categories - articles that told stories of people with a problem and articles that detailed the research process itself.

When the articles focused on stories of people, the main heroes were scientists, doctors, or science writers. But unlike with other articles, their struggle was not connected only to the research. In Science scientists often tried to deal with regular human problems. In the 'One of our reporters tried to do CRISPR. He failed miserably' the writer of the article attempted to perform a CRISPR operation. That his attempted was set as a challenge, he wanted to overcome. The story did not have a positive resolution, but the writer's takeaways from experience were treated as a conclusion to his efforts. (Cohen, 2016) In the same way, 'Ailing fetuses to be treated with stem cells' was mainly focused on the story of a doctor that has been performing stem cell surgeries. Oliver himself has been struggling with an osteogenesis imperfecta - which means that his bones can break even when he performs routine tasks. It is the conflict of the

story, and how overcoming the everyday challenges are set as the resolutions to the conflict. (Couzin-Frankel, 2016) In both of those articles, the science behind ideas is not the main focus of the story, but it only complements it.

The other six articles though different in their style, approach to the topic, used similar storytelling framework. Their main focus was the research process. The ‘Seventeen volunteers let this worm live inside of them to help defeat a dangerous disease,’ and ‘Changes in gene activity may one day reveal the time of death for crime victims’ reported on the biology-related researches. The conflict in those articles was the difficulty with which scientists often conduct a study. The resolutions to those conflicts were speculations about possible positive consequences of the study. (Kupferschmidt, 2018; Pennisi, 2018)

The other two articles were about medical research. In ‘Dare to do less,’ and ‘This protein is mutated in half of all cancers. New drugs aim to fix it before it’s too late’ the writers described why the medical research was conducted. In both cases, the reason was an ill patient whom the researcher or a doctor wanted to help. The conflict of the story was the unresolved medical issue, and the resolution was in the lack of resolution at the point when the article was written. (Marshall, 2014; Service, 2016) Those articles functioned as research proposals, giving ideas about possible future research areas.

In the ‘How Pluto's most spectacular image was made—and nearly lost,’ and ‘Mars rover steps up a hunt for molecular signs of life’ similar approach was taken. Here the focus was Space science. In the first case, the conflict was one of the scientist's mistakes, and attempt to solve the problem. It had a positive resolution, with scientist finding eventually managing to find the image. The article tried to focus on the environment in which scientists work. (Hand, 2015) The other article details on how scientist solve problems. That problem-solving process was at the

heart of the conflict. Finding an alternative use for the rover was the resolution to the problem. (Voosen, 2017) The storytelling articles about space were different from the other ones because they were not set around actions of the scientist, but rather their observations and predictions. Those interpretations of those interpretations though easily formed into the classical narrative structure.

Overall, the articles published in Science showed how science publications could write engaging and compelling pieces about difficult scientific ideas, without sacrificing the quality of information presented. Science shows that the writer does not need to have all the answers. With sciences, positive closure to the story is not necessary, and with many stories, it is even not unrealistic. It did not set a ready story beforehand and used information to form a pretty picture, but focused on humanization of the research process itself, giving a human face to dry and jargon-heavy research papers.

Nature

About Nature

Nature is an academic journal that publishes original scientific research papers. It also has an online magazine that regularly posts about research projects in the field of sciences. The magazine the scientific journal itself score high on credibility metrics. Unlike other sources selected for the research that have originated in the US, Nature is British journal. The magazine is the top journal in the field of science, and one of the top journals that publish original research works across industries. Nature publishes papers on a variety of topics and covers a wide range of environmental, physical, biological, and health-related original topics. The journal is part of

the Nature Publishing Group - the same company that publishes Scientific American. (History of the Journal Nature, n.d.)

Its first publication dates back to November 1869. The journal's main audience are researchers, but the magazines also publish many articles that summarise findings using accessible language. The journal also reports on news in the field, covers policies, and analyses implications of research. Those sections intended for a more general readership are presented at the beginning of the journal's issues. The rest of Nature's weekly publication consists of highly technical overviews of different research works in the field of science. Since the creation of a digital version, articles in the print version become more condensed, with their technical versions being published on the website of the journal. It is known in the scientific community for its high publishing standard. Less than 8% of the papers submitted to Nature get published. (Fersht, 2009) The journal claims that Nature's website is visited by 3 million unique readers every month. The circulation rate of the weekly journal is more than 50,000, and more than 400,000 people read each issue. (Springer Nature, 2018)

It started out as one of the many scientific journals in the 19th century but in the result considered managerial decisions transformed the journal into the leading journal in the field. One of the factors that contributed to its long-lasting success was the Nature's willingness to take risks with research findings and articles it published. The journal's editorial board avidly supported Darwin's theory of evolution from the very beginning and advocated for publication of other controversial at the time researches and ideas. (History of the Journal Nature, n.d.) The journal has expanded into many branches towards the end of the 20th century and opened many offices around the world. Currently, there are more than seven journals among Nature

Neuroscience, Nature Biotechnology, Nature Methods. All Nature's other publications are considered to be leading journals in the field of their studies.

Being published in any of Nature's journals is considered to be very prestigious. It is one of the most highly cited journals in the world across industries, which also means that writers get high visibility and access to other resources after publication. Many of the most important scientific researchers like the paper on the structure of DNA, published by Watson and Crick, have been first published in Nature. For that reason, publication standards of the paper are high and strict. Outside of being scientifically valid, the paper also needs to be 'ground-breaking and important enough' to be published. After that criterion is met, the research gets reviewed by editors, and then goes through a rigorous peer-review. (Nature.com, 2018)

With the creation of its online publication, Nature also started publishing reviews of academic papers and news, many of them available for free access. Those stories available online often use storytelling in the way they present scientific content. The first thing on the landing page is three latest news stories that are related to the research papers published in the magazine. Right after the news section comes a link with an image of the latest issue of Nature, which gives visitors an option to either subscribe to the journal or look through its content. It is the only mentioning of the subscription to the journal on the website's main page. The next section is Latest News, which has six news stories updated daily. The articles have small images, short titles and briefs of article's content under the image. The pictures attached to the article are more technical than in other magazines. After the news section comes the section with latest research highlights with three articles in it. In most of the cases, to access those articles, you need to be subscribed to the journal where the article is featured. A browsing section follows the research highlights, and readers can use it browse through journal by subject (biological science, earth and

environmental, health science, physical sciences, the scientific community, and society). Each topic has an inbuilt statistical tool that shows what the most popular topics within those subjects based on the number of papers published in the journal are. The last section is a career section with articles for professional researchers.

Just as Science, Nature does not heavily push its subscription to the visitors of the website. The magazine also allows for third-party free access to the articles published in the journal if someone who owns a subscription shares them. The subscription to a print and digital version costs €210 and €125 for students. The website does not have sponsored content. Other than subscriptions, the journal gets its revenue from the researchers. To submit papers to the journal you need to pay a flat fee, which ranges from \$1100 up to \$5500 depending on the journal and discipline. (Noorden, 2013)

The articles in Nature are usually reporting on the inside scientific culture. The journal's stories are written as insiders perspectives on how scientific researchers affect the bigger world.

Analysis of Articles from Nature

In the stories in Nature, science is not disconnected from the reality and scientists are not presented as people outside of the real world. Unlike with Nautilus and Scientific American, a life of scientists was not represented as a separate alienated existence where problems were only matters of research. They were portrayed as a community of people connected by their profession. The content thus was also more professional, orientated towards a more scientifically literate audience.

For when it comes to formatting, it is worth mentioning that the journal also handled it more professionally than other journals did. All articles in Nature had short summaries of key

ideas to discussed at the beginning of the article. When the information in the original article was not accurate or full, at the end of the article writers included notes explaining what change was and for what reason. References to studies were also properly cited after the article, not included only as links within the text. All article were also were divided into a section with headlines, usually making a differentiation between ideas that are going to be discussed from that point. Articles themselves though flowed coherently, with headlines used to help navigate a reader through long pieces rather than change a topic.

Even though many of the articles, selected for the analysis, had a narrative story their language was direct and less literary. As it was established before, Nature is written for researchers and scientists. That also means that metaphors and similar linguistic tools that help explain and connect ideas through relatable images were not as necessary. The literary tools were employed in rare occasions, often in the form of similes describing feelings of scientists more than the science behind a presented idea.

The main distinction between stories chosen from Nature was the point of view of narration. Four of eight articles revolved around an accident that happened to one person. The rest of articles followed a group of people or an ongoing point of debate in sciences. All of them used storytelling as only an element of an article, shifting to a more objective perspective later in the article.

In the stories that had a hero, the entire plot was driven by an event or an idea that they encountered in their regular non-research related life. In the ‘As Cape Town water crisis deepens, scientists prepare for ‘Day Zero’ the entire storyline was created around Jodie Miller, a scientist from South Africa. One day, when baking cupcakes she discovers that their water supply has been turned off. Her inability to do something as simple as baking was set as the main conflict.

The explanation of why it happened and what can be done to solve the problem was set as the resolution to the problem. The story was mainly set in the beginning and was not referred to back again at any other point of the article. In its body, the article detailed on current researchers, scientific opinions that promised to solve existing problem. The storytelling in those articles was used to give a human face to the problem. The case only illustrated an example of how a problem with a scarcity of water resources affects people in real life. (Maxmen, 2018) The same approach was used in the 'Theatre: The bladder's tale.' The article made a quick overview of the entire field of bladder cancer research on the example of the writer who has dealt with the experience of fighting it. The conflict was set as the performer's diagnosis with cancer. The resolution was her coping with the diagnosis using scientific knowledge to create a performance. (Worth, 2017) No clear solution was provided to the problem of cancer, but the art became a resolution to the human problem, set as the main conflict of the story. Science or medical research was not presented as absolute knowledge, but as an ongoing field with many problems that do not have a clear solution yet.

The other two stories with a single hero were longer pieces that touched upon several fields of sciences. They had more detailed descriptions of the researchers and the science behind them. In the 'Fiction: The science in Sherlock Holmes' the story was set around a familiar character. (Konnikova, 2017) The article tried to show how the character was created and which ideas in fields of sciences - like medicine, chemistry, and biology-inspired his creation. The willingness to understand the science behind Sherlock's adventures was set as a problem. The resolution was found in history - the article concludes that the famous detective is a collective image of sciences of the time. The last story in the section is the story of Mark Price named 'Genetics: The hexanucleotide hex.' The story revolves around a family that has a history of

being diagnosed with ALS. The conflict is Mark Price's desire to understand whether his illness is hereditary and if yes if the gene has been passed to two of his daughters. The resolution in this story is not positive. Later in the article, it is revealed that the gene has been passed to his daughters. The story is set at the beginning of the article, and the writer gets back to it only at the end of the article. After the description of research, the writer tells that Price's two daughters who can be diagnosed with ALS, made a decision not to have kids without checking the cells first on the presence of the gene. (Dolgin, 2017) The rest of article describes what is the science of a mutation, and how researchers go about addressing the problem. It is highly technical and covers many of the ongoing research in the field of ALS gene mutation in details.

In the articles where the main focus was on research, the main story revolved around it and presented researchers directly engaging with the field of their study. In the 'Cosmology: A story of cosmic proportions' two writers attempt to write a book about the origin of the world. The conflict of the story is set in scientists finding the right approach to tell the story of the universe. Each of the writers choosing a different approach to the same subject and that becomes a resolution to the set problem. The story in this article is the research process itself. (Turner, 2015) Through this article, Nature makes it clear that scientific research in itself has a dramatism that can be exploited for storytelling purposes. The other story continues elaborating on that trope, using dramatization of a scientific process to tell a story. In the 'The drug-maker's guide to the galaxy,' chemists are the main heroes and their research task - to find an appropriate formula for a drug - is set as a challenge. Their quest for the right formula makes one of the researchers create an algorithm, which quickly scans through different options. (Mullard, 2017) That creative approach to the set problem becomes its resolution. After the conflict is resolved, the rest of the

article focuses on addressing ethical and technical problems of experimenting with algorithms. The story is set as an example the writer uses it to illustrate the point it wants to make.

The next story that made research practices its main focus also addressed the concept of computer simulation in sciences. In the 'How to blow up a star' the team of researchers attempts to simulate the process of blow upping a star. The process of figuring out how to do in the computer simulation becomes a resolution to the problem. In this story, we go along with researcher that adjust their formulas and algorithms to make a correct simulation. (Gibney, 2018) In the 'Beguiling dark-matter signal persists 20 years on' the heart of the story is scientific skepticism. It is centered around the controversial research that claims it detected the existence of a dark matter. It comes from a research institution in Italy, that does not have a huge following among scientists. The controversy around the subject thus becomes the challenge and the team's attempts to convince scientific community in the validity of their research by improving their methods and equipment, is how the problem is attempted to be solved. (Castelvecchi, 2018) The article tells a story of scientific research and the 'monsters' they need to face while demanding an acceptance.

Overall, Nature's articles were different from the other not only in their format but also in the language they used and the audience they addressed. Unlike other journals, the preference was made towards simple, not fictionalized language. The narrative was revealed and set mainly not through literary tools, but through structure (character - conflict - resolution). Subjects their addressed were small-scale and specific. In Nature, articles were written mainly to overview the research that is currently done in the field and present what it has achieved. The use of storytelling in Nature showed that storytelling does not need to have to be a defining aspect of an article, but can be used to make a point or illustrate an example. Storytelling can also help reveal

gaps in research and look at scientific problems from a human perspective. Nature makes the best case for not drawing a clear line between storytelling pieces and purely reporting pieces, but using the two at the same time. The article in Nature, showed how storytelling could be employed in sciences not only to communicate ideas but also used to reflect on the subjects analytically.

National Geographic

About National Geographic

National Geographic is the only magazine in the list that is not centered only around sciences. It covers a wide range of topics, including geography, history, and world culture as well sciences. It is one of the largest educational journals in the world. There are more than 40 local-language versions of the journal. According to The Washington Post, its global readership exceeds 6.7 million. Today, the magazine has a monthly circulation of around 8 million, with a global readership of 60 million. (AAM, 2017)

National Geographic has been publishing new issues since 1888. It is the official magazine of the National Geographic Society, that has been founded right after the establishment of the foundation. The magazine has shifted from being a small-scale magazine, published for a small circle of devoted professionals to a media giant. Now it tells stories through a more personal lens, detailing of different human experiences. National Geographic took a field of science - geography, which is still the main focus of the magazine - and made it mass appealing. In that term it is a unique phenomenon - no other science magazine has owned the same credibility and cultural following as National Geographic. The magazine's longevity and popularity can be credited to one of its early editors, Gilbert H. Grosvenor. The editor-in-chief invested in the

development of a strong sense of identity, without compromising to the innovative culture of the journal. Under his governance, the magazine became a globally recognized trademark it is right now. (NationalGeographic.com, n.d.) The thick square-bound glossy format of the magazine and the square logo is one of the most recognizable identities in the world. The magazine also effectively developed its own style of dramatic documentary photography, which dictates standards of documentary photography around the world even right now. Some of the world's most renowned images were commissioned by National Geographic. The magazine became also an advocate for sciences and has been the first to speak on many controversial topics like pollutions, illegal trade of rare animals, and scientific literacy. (Foster, 2012) Besides being one of the most popular media outlets it is also known for its accuracy and scientific credibility.

It won multiple prestigious awards and currently has 13 National Magazine Awards, for both its content, impact, and marketing. (Foster, 2012) The magazine has branched off into other popular publications like National Geographic Traveler, National Geographic History, National Geographic Kids, Maps, and many more. It uses different mediums to tell stories, including film, literature, photography, and many more. Unlike other science magazines, National Geographic has embraced usage of interactive media in its storytelling. The magazine proactively uses technologies to create supplemental maps, detailed infographics, and close up views of atoms and cells. The print and digital versions of official issues come out monthly. The website posts stories and news coverage on a regular basis. The digital version also has exclusive available interactive content for subscribers. National Geographic also prints extra issues around interesting ideas, occasions, and popular topics. Magazine's issues often have a theme that is related to a history, an idea, a country or a person. The company has evolved into a media company with its own channels, tv shows, and merchandise.

National Geographic has a diverse audience. As was mentioned before, the magazine has a large readership and it is invested in keeping all of them interested in its content. But more or less, the journal is orientated to the people interested in education and learning, and not necessarily scientists and researchers who have an in-depth knowledge on a specific subject. For that reason, the main focus of the magazine is people and their stories and the science behind the phenomenon. For those readers who are interested in studying more about the subject, National Geographic articles offer additional resources, links, and interactive images. All of the articles are layered and can be appealing to different readers.

Sciences have a separated section on the website, but the digital version of the magazine is not solely centered around them. The main page of the website is as an overview of the entire magazine with a news section on the top, promotion of the magazine's documentary show below it. Then comes a section with the most popular stories from the journal and other content published in cooperation with the magazine. (photography, TV-shows. videos), and at the very bottom subscription advertised to its latest issue and an overview of its content. The main page has only two advertisement banners, which have the same ad.

Unlike other journals, National Geographic has only three subscription options. There is a Digital version, a Print version, and a combined version which cost \$23, \$54, and \$70 respectively. All of them are one-year subscriptions, which includes 12 issues.

Alongside travel, Animals, Environment, Cultures, Adventure, History, Photography, and Video, Science has a separate section with the journal within a journal. On the top of the page, there is an invitation to subscribe to the journal. After that comes a navigation bar, which breaks the science section on to three other main topic - space, human origins, and prehistoric life. The next part of the science page consists of three articles from the Space section. Then comes the section

dedicated to the latest stories, and a separate interactive piece. Closer to the bottom of the page, the page features science videos and a science-related piece from the new issue of the magazine. The interactive media pieces with multiple media elements are available only to subscribers. Titles of the articles in the magazine are long and often either summarise the main idea from the article or ask a question. They are never provocative and always reflect the tone of the content. All articles are accompanied by original illustrations or photos. It usually published news articles, or opinion pieces, as well as special essay-like articles with a critical or original view on the familiar phenomenon.

Analysis of articles from National Geographic

Many of the articles in National Geographic had storytelling elements to them. The magazine is focused on the delivering stories about people, sciences, and cultures. Unlike other science magazines, stories are the main focus of the magazine, and that is apparent from the articles selected for the analysis. All of the articles had inherent storytelling the aspect to them and revolved around documentary narratives told by a writer. Some of the articles had a central theme and then retell multiple stories illustrating different perspectives on the subject. The detailed scientific models were done using illustrations and visuals. The text was mainly used to convey a story with rear explanations of terms and concepts in between. In the National Geographic, stories were not only closing and opening articles, but they were spread out through the entire article revealing them bit by bit.

The content of the articles in National Geographic is summarised before the article in a couple of sentences. The paragraph are small, written in a large type and have hyperlinks to other articles in the magazine or other publications. Most articles had subheadings in articles, and

many of them used bold and italics to highlight important ideas. Unlike other publications, all articles in the National Geographic were accompanied by photographs, exclusively commissioned by National Geographic with lengthy captions. Some of the articles even revolved around stories connected to the photos and photographers. Articles were relatively short and easy to read.

The articles were not analytical, but story-driven. They explored the adventures of the scientists, reporting in the feature stories. The articles were written in an accessible language and did not use metaphors to explain ideas. But many of the pieces used dramatization and popular culture references to help build stories and characters.

As was mentioned above some of the stories in National Geographic were centered around one story, but some gave multiple perspectives or several stories within the one. That was the main difference between articles selected for the analysis.

The first article that had multiple stories with itself is ‘The Amazing Dinosaur Found (Accidentally) by Miners in Canada.’ The first and main story in the article revolves around a miner Shawn Funk who accidentally came across a strange-looking fossil and did not know what to do with. After a while, the geologist learned that it was an entire skeleton of a dinosaur preserved in an excellent condition. After that, the main story branches off to other stories that tell the same story from perspectives a geologist, and the owner of the National history museum. (Greshko, 2017) The article showed the influence a discovery can have on different people and institutions by showcasing those different stories. The next story is ‘NASA's Juno Spacecraft Is Now Orbiting Jupiter.’ It two perspectives on the same idea. First, the story is told from the perspective of a spacecraft that completes a complicated maneuver to land on the orbit of Jupiter. The enters it, and that is presented as a resolution to the conflict.

(Drake, 2016) After that story is told, the article moves on to recreate the same story, looking at the cosmos through the eyes of scientists. For them, the whole journey of the space machine is full of conflicts and solutions. The article does not detail on the science of developing the spacecraft or how maneuverings are done, but focus more on the storytelling perspective that the expedition inherently has.

The other article that had multiple stories within itself was ‘Einstein’s Relativity Explained in 4 Simple Steps’. Here Albert Einstein is presented as both a curious student that struggles with the conventional educational system. That is his first conflict, which is resolved when he attends an alternative education in a special summer school that nurtures his visual thinking. That story builds up to another story that is centered around the idea of relativity and how scientists struggled to formulate it correctly. The resolution to that is the scientist's step-by-step action guide to all the problems that he came across while developing his theory. (Waldrop, 2017) The article uses the image of the popular scientist and a storylike aspect of his life to explain a scientific phenomenon, using simple words and vivid examples. The last article that also has several stories within itself is ‘Does the Loneliest Plant in the World Need Help?’ that gives two different perspectives on the same story. The main difference between those two stories is time and history. In the first story, a scientist John Medley Wood discovers a strange tree. He struggles to identify to which category the tree belongs and that is set as a conflict of the story. At the end of that arc, he identified the plan as one of cycad, an ancient order of trees. Fast forward, and after hundreds of years scientists learn that it is not one of the cycad plants, but it is the only one of its kind left on Earth. (Krulwich, 2016) The conflict is set as scientists is to find a pair to a lonely tree. The resolution is in genetic engineering, which already has helped to develop a model that is similar enough to tree. The article does not go in an analysis of biology,

genetic, and botanicals, and genetic engineering, but overviews how the three the problems are solved in those fields. It elaborates on inherently more storytelling aspects of the story.

In the rest of the articles stories revolved around one subject. Unlike other journals through the articles in National Geographic were usually constructed not around concepts and people, but around subjects or happening and events. In the 'In Unprecedented Loss, Endangered Whales Die of Mysterious Cause' conservationists investigated the mysterious case of the sudden whale deaths. The unfortunate accidents are set as a conflict. The resolution of the conflict is presented as the conservationist attempts to understand what caused the death of those animals. In the article, the writer does not detail the science of their deaths. (Gibbens, 2017) The main perspective is moralistic. The resolution in this article thus is not reached through sciences and scientific explanation but presented as a human judgment. The other story also explores an accident that might not have been covered in other publication. 'An 80-Year-Old Prank Revealed, Hiding in the Periodic Table!' tells a history of a joke, played by a scientist. It is an unusual approach to sciences, which uses a different tone in its storytelling altogether. Glenn T. Seaborg is the hero of the article. He is asked to come up with a name for an element he discovered - plutonium - for the periodic table. That is presented as a conflict. The story goes on to describe the hardships the scientist faced when coming up with a name for the radioactive element during the war. In the end, he decided to play a joke and names the element Pu, hoping that kids would find it funny. The resolution of the story is presented as a punchline to the anecdote. (Krulwich, 2015) The story touches upon the logic of periodic table, and explain the importance of elements discovered by the scientist, but the main focus of the article is delivering the funny story.

In the 'Jam: Chemistry and Cool in a Jar' the writer uses science to entertain an idea. The main hero of this article is the reader. In the narrative, the writer takes readers on the jam-making journey, describing the science of the process of step-by-step. The question was submitted by the reader. The writer resolves the question by detailing on the chemistry of the jam, bringing an example from Maria Currie's like, and telling the history of the treat. This article showed how the audience could be engaged in the sciences and sciences storytelling. All the questions that the audience wants to be answered can be potential conflicts. (Rupp, 2016)

The writer can use that conflict and interest in the subject and present a resolution using scientific perspectives, thus educating and entertaining the reader at the same time. The last article 'Meet the Crews Preparing for Human Life on Mars' told the same story as 'My Year on "Mars"' from Scientific American. But in the National Geographic, the story was covered from the perspective of the photographer for the magazine. The change of perspective turned it into a different story. The hero is a photographer, who is asked by the magazine to capture life conditions of scientist that live in the simulated Mars environment. The task is the conflict, and the authenticity becomes the resolution. (Drake, 2018) Basically, in this article the resolution of the story is a personal journey, thinking process, process of creating a perspective. The science here plays only supports facts that help to form a perspective. In the article, the writer illustrates how the science can impact our physical existence, thinking, and spiritual life.

Overall, stories from National Geographic are examples of bold storytelling. Unlike, Science and Nature, which favored more neutral perspectives to subjects, National Geographic pieces were bolder and made stronger arguments. The magazine shows how narrative structure can be used to highlight the naturally adventurous characteristics of sciences. Since the magazine's audience is less scientifically literate, articles had an entertaining quality to them

and were written in the simple and accessible language. When they elaborated on scientific concepts, it was done in the way that would not interrupt the flow of the story. National Geographic also made a case for presenting scientific ideas from multiple perspectives, enabling the same idea from professional scientists, or regular people.

5.2. Literary Tools

Science stories published in the science magazines not only had a classical three-act structure, with characters, conflicts, and resolutions, but they also used similar literary tools, often used in fiction, to help tell those stories. As in all fictional narratives they made the text more exciting, added more dynamics to the story. But their role in the process was different. Literary devices often had an added value in the science communication texts. They were used not only to support narratives, but to explain, connect, and explore different ideas. Their role in the articles was as important as the structure itself because besides being an entertainment, science communication also has an added purpose. Science communication should simplify, educate, and engage and those functions were attempted to be realized through the usage of the literary tools.

The articles selected for the analysis used many more literary tools than described above, but the ones selected from the list were most prevalent among the selected sample. Some of them have been anticipated (like metaphors and anthropomorphism), but many came from the research process itself (like popular culture references and foreshadowing). At least one of those literary devices has been used in each article.

- **Metaphors/Similes**

Metaphors and similes are literary devices used to make comparisons. Metaphors are subtle, defined as the transfer of a quality from one thing to another. Often those two things or ideas have something in common. Similes have a similar function, but unlike metaphors, the comparison is made obvious by the usage of words like 'like' and 'as'. (Faculty of English, n.d.) The devices are often used to enrich the text.

In the science communication narratives, they were used to explain a scientific process in an easy and accessible way by comparing difficult concepts to familiar imageries and ideas. Sometimes metaphors were used to tell the story. In some other texts, they were mentioned only to ease an understanding of an idea or concept. Similes were used even more frequently. Both of the tropes were used to describe feelings as well as ideas. Metaphors in science communication have an added value because they not only make the text rich but help to make ideas more accessible to the wider audience.

Metaphors and similes were more frequently used by the journals that were addressing a less scientific audience. The metaphors were used most of all in the articles from *Nautilus*, which is known for its more literary style of writing. It was one of the most common devices used in the texts. Together with similes, original metaphors as significant plot driving devices were used in 17 articles from 40.

Examples:

'Called p53, the protein sounds the alarm to kill cells with DNA damage and prevent them from becoming cancerous—one reason why it has been called the "guardian of the genome." - from 'This protein is mutated in half of all cancers. New drugs aim to fix it before it's too late,' *Science*. (Service, 2016)

‘Sticking with the earlier toy theme, she compared herself post-surgery to a Betsy Wetsy doll, which wets itself after drinking water.’ - from ‘Theatre: The bladder's tale,’ Nature. (Worth, 2017)

- **Humor/Anecdote**

The humor and anecdotes are inherently narrative tools. Anecdotes - the short verbal accounting of a funny, amusing, interesting event or incident (Literary Devices, n.d.) - often have the classical three-act structure inbuilt to them. The humor is also often used in stories that have storytelling context, but unlike anecdote, the humor can be transferred through a tone of the article and not only the story. They are used to entertain and tell stories.

In the science articles, they played a similar role. The human and anecdotes ease the reading and help integrating human stories into the articles. Many of the articles used a humor to tell stories that people would find easy to connect with, thus cutting the distance between the scientific world and people. It was frequently used in the biographies of scientists, making them seem more human and real. It was also used when explaining difficult subjects, to ease the reader and soften the sense of inferiority. Humor reminded that sciences are done by people for the people, and avoiding funny stories would have been not possible. The literary devices made difficult subjects more approachable.

The trope was more common in biographies and stories that had historical references and less common in the news articles. Humor and anecdotes had a significant role in the narrative of 8 articles from 40. (from which journals)

Examples:

‘The oligo arrives, and I lose my modern pipetting virginity.’ - from ‘One of our reporters tried to do CRISPR. He failed miserably’ Science. (Cohen, 2016)

‘And there it remains. So any time you like, you can look at one of humanity’s greatest intellectual creations, posted in classrooms all over the world, a table that organizes all the stuff of the cosmos into a coherent map, and smack dab at the bottom, somebody’s whispering, “pee-you!”’- from ‘An 80-Year-Old Prank Revealed, Hiding in the Periodic Table!’ National Geographic. (Krulwich, 2015)

- **Popular culture**

Popular culture references and references to the culture that we assumed to be understood by many are not considered a literary device, but it has been commonly used in the selected sample of articles. Other journals and publications also use references to popular culture, in order to connect with a larger audience. Science publications used it to increase the readership, and make a connection with the real world. Popular culture reference helped to make ideas published in the journal more human and brought original perspective.

It was used both to illustrate an example or as a lens and a perspective through which the entire topic can be viewed. Popular culture can appeal to a wider audience, without a need of simplifying the context and using sensationalist titles to attract the reader. Even though the articles were selected randomly, many of them had references either to a popular culture or to ethnic culture. Some of the articles used the popular culture as the main storytelling driving point, some only illustrated examples using references to it. The trope has been used in the seven articles. Nautilus and National Geographic used the trope the most, which is understandable if we

consider that they have they aim to connect with a wider audience that does not have experience with sciences per say. Popular culture references in at least some form were present in 14 articles from 40.

‘Bioengineering plays into nightmares about the not-quite-human that have long haunted the West’s historical imagination, from the Prague Golem to vampires, werewolves, the monster in Mary Shelley’s *Frankenstein*, and the evil automaton David in Ridley Scott’s 2012 film *Prometheus*.’ - from ‘Encounters with the Posthuman,’ *Nautilus*. (Davies, 2015)

‘He pointed to various features on the screen with a Dumbledore wand he had picked up at a Harry Potter store in London. (“If I’m going to be doing tricks with image processing, I might as well have a wand,” he wisecracked later.)’ - from ‘How Pluto's most spectacular image was made—and nearly lost,’ *Science*. (Hand, 2015)

- **Opening and closing with a story**

It is not a formal trope used in the literature, but it was frequently used in science articles to grab the attention of the reader. As was mentioned in the literary analysis, stories are easier to understand and relate to and by showing that there is going to be a story in the article at the beginning, the writer can increase interest in the content of the article.

But transforming the entire scientific research, especially with more technical terminologies is a challenging and tricky because sometimes it means that the accuracy of the information should be put aside. That is why in many of the narrative articles selected for the research, a story only opened and concluded the article. In most of the cases, stories were either

entirely presented in the beginning and referred to again in the end, or presented the hero and the conflict in the beginning and provided the resolution to the problem in the end. Often the resolution was a science or scientific analysis presented in the main body of the text. Opening-ending with a story format was used in 6 out of 40 articles.

Examples:

‘Fourteen years ago in Bremen, Germany, astronomer Seth Shostak gave a lecture that included a wager. “I bet everybody in the audience a cup of Starbucks that we would find E.T. within two dozen years,” he told a new audience in October.’ opening sentence; ‘Shostak also brought up a less frightening but perhaps more existentially dreadful possibility about some future first contact: what if we finally hear from aliens broadcasting their presence as sentient beings, and the big announcement is their understanding of well-known mathematical phenomena such as the Fibonacci sequence.’ closing sentence - from ‘Intelligent Aliens May Know about Us Well before We Find Out about Them,’ Scientific American. (Mirsky, 2018)

‘Last spring I came to know a pair of pigeons. I’d been putting out neighborly sunflower seeds for them and my local Brooklyn house sparrows; typically I left them undisturbed while feeding, but every so often I’d want to water my plants or lie in the sun. This would scatter the flock—all, that is, except for these two.’ opening sentence; ‘As for Harold and Maude, I don’t know how their story ended, or indeed whether it continues. They roosted in a partially abandoned building on my fast-gentrifying block. It’s now being turned into condos, making them victims of Brooklyn’s rising real estate prices, albeit with a better

chance than most humans at finding a decent place to live nearby.’ closing sentence -
from ‘What Pigeons Teach Us About Love,’ Nautilus. (Keim, 2016)

- **Anthropomorphism**

Anthropomorphism is assigning human traits to nonhuman things and objects. It is often done to animals and nonliving things and it is a way of creating a character, often used in diction.

(Literary Devices, n.d.) It is used to create and develop interesting characters and often adds a fantastical element to the conventional narratives. The literary device helps to animate objects and illustrated their behavior using accessible language and allusions.

It is especially valuable in the science communication because it allows explaining scientific process without a need of human characters. By connecting their behavior to the familiar to us images, it becomes easier to understand and memorize the concepts. It was frequently used in the science feature articles where the writer’s main goal was to illustrate a concept or an idea, especially considering that scientists are often working with non-human entities. The elements and animals were given human qualities in 13 out of the 40 articles.

Example:

‘There: See that electron? It’s a building block of Guerre himself. But what if we were to put the electron on trial inste/ad of Guerre?’ - from ‘Quantum Mechanics Is Putting Human Identity on Trial,’ Nautilus. (Geftter, 2015)

‘Somewhere, on the side of a hill, tucked up against a rock, hanging in a shadow, I can still imagine a shy female E. woodii’ - from ‘Does the Loneliest Plant in the World Need Help?’ National Geographic. (Krulwich, 2016)

- **Emotional language and drama**

When using dramatization, the writer using emotional not factual language to pose something as more dangerous, important, and exciting than it actually is. (Literary Devices, n.d.) It makes heroes and their adventures sound intriguing and more distant. It is often done to build up suspense, using a language that is full of emotions. The trope feels counter-intuitive to what sciences are expected to do, but other types of non-fiction literature have been employing dramatization for as long as writing has been used as a medium. In the science communication, it has been used as a way to clearly separate the story from the science and create a more compelling narrative, that would present a scientist or an event in a memorable way.

Science communicators also see potential in the usage of that fictional trope. The emotional language with drama has been used in 12 articles out of 40.

Example:

‘Gulbranson and his colleagues have to disembark from planes landed on snowfields, then traverse glaciers and brave bone-chilling winds.’ - from ‘280-Million-Year-Old Fossil Forest Discovered in Antarctica,’ Scientific American. (Pappas, 2017)

‘A high-profile failure—or worse, injury to the mother or her fetus—could set the field back decades. “That’s what keeps me up at night,” David says. “Safety, trying to tick all the boxes, thinking as much as possible” about everything that could go wrong.’ - from ‘Ailing fetuses to be treated with stem cells,’ Science. (Couzin-Frankel, 2016)

- **History**

Though not being a literary tool per se, historical references were often used in science articles to illustrate a point or add a story to the concept. The historical ideas have a storytelling structure to themselves, and that inherited format can be explored for storytelling purposes when communicating scientific concepts. The scientific ideas in those articles often neighbored with the historical perspectives and stories of people. It has been used in many of the articles from the sample not only as a driving point for the story but also as a way to branch off the main story to some other when necessary. It is a creative tool, which can help sciences seem more human and place them within a context. It has been used in 15 articles out of 40.

Examples:

‘In 1812, Massachusetts governor Elbridge Gerry signed a bill that redrew some voting districts to benefit his party. One odd-looking district wrapped around the city of Boston in the shape of a salamander. Political satirists dubbed the new district the ‘Gerrymander.’” from ‘The Mathematicians Who Want to Save Democracy,’ Scientific American. (Carrie Arnold, 2017)

‘A tidal wave of such ambiguous cases began to pour into clinics in the early 1980s,’ - from ‘Dare to do less,’ Science. (Marshall, 2014)

- **Amplification**

When the writer adds more information to the existing story to increase the worth and understandability of the text the writer uses amplification. Writers use amplification to complete a sentence that otherwise would have seemed abrupt, or the meaning could have been not

covered properly. (Literary Devices, n.d.) The information is often added to the sentence in parenthesis or separated from using dashes.

Since scientific ideas are not easy to understand, many of them used amplification, when describing an idea. By using amplifications, a writer can add information about concepts and ideas without a need to break the story to explain an idea that was mentioned before. It can help to present information to the main plot or explain the concept without a need to revolve the story around it, or use lengthy paragraphs to branch-off and explain an idea if it does not carry a plot-relevant meaning.

In the articles selected for the analysis, amplification has been used the most by Nature and National Geographic. Though all the journals occasionally added information to the existing sentences in parenthesis or using dashes, those two journals did it the most. The amplification has been used in 13 articles out of 40.

Examples:

‘These “core collapse” explosions make up around two-thirds of all supernovae. (The other sort, known as type Ia, involves a fusion-driven explosion of a white dwarf.)’ - from ‘How to blow up a star,’ Nature. (Gibney, 2018)

‘That voyage took five years and covered 1.7 billion miles (2.7 billion kilometers). But the hardest part came at the journey’s end, when the spinning spacecraft’s engines needed to burn with laser-like precision to help slow Juno down so that it could order for becoming Jupiter’s newest—albeit temporary—satellite.’ - from ‘NASA's Juno Spacecraft Is Now Orbiting Jupiter,’ National Geographic. (Drake, 2016)

- **Foreshadowing**

Foreshadowing is used to hint at how the story is going to unfold before telling the main story. It makes use of indicative words and phrases and hints the reader on how the story might end or how it ends. It is a tool that creates a dramatism. It is also frequently used in science communication narrative articles.

It is used as a transition between the narrative element and scientific explanation of what has happened. By using foreshadowing, the stories can keep the reader interested while moving on to explaining the sciences and then come back to the main story points. It helps to connect the science to the real world, letting the reader make conclusions before the real connection is revealed. It is a dramatic narrative tool that has been used in the five articles from the selected sample of 40.

Examples:

‘In an intimate, packed theatre at the Kansas City Fringe Festival in July 2017, Mechele Leon took her audience on a journey that began with the discovery of blood in her urine in March 2016 and ended with the removal of her bladder later that summer.’ - from ‘Theatre: The bladder's tale,’ Nature. (Worth, 2017)

‘On the afternoon of March 21, 2011, a heavy-equipment operator named Shawn Funk was carving his way through the earth, unaware that he would soon meet a dragon.’ - from ‘The Amazing Dinosaur Found (Accidentally) by Miners in Canada,’ National Geographic. (Greshko, 2017)

- **Juxtaposition**

The juxtaposition is the literary device which is used compare two different things and ideas with each other, to find differences or defined similarities. Juxtaposition often implies parallelism, meaning that two ideas or people are compared to similar standards and against similar criteria. (Literary Devices, n.d.)

It is one of the tropes that helps to compare one idea to another. In science, storytelling is often used to reveal controversial perspectives and present ideas that have historically. It is a powerful way of contrasting an old with a new. It can be used to debunk stereotypes about sciences and common misconceptions in the scientific community. The tool also implies that a storytelling idea, and can act as the source of the conflict itself. Thus by presenting one idea in opposition to another, the writer can have a story without constructing it from scratch. It is often used to defined ideas, and study them in closeup, which is a format that works in sciences well in sciences since many ideas have multiple perspectives. Since it is often dramatic it also inherently sets a narrative structure. It has been used in 4 articles from 40 articles selected for the analysis.

Examples:

‘Jim Baggott's *Origins* and Lisa Randall's *Dark Matter and the Dinosaurs* recount the greatest story ever told: the evolution of the Universe since the Big Bang. This rich cross-disciplinary tale reminds us that astronomy, physics, chemistry, geoscience, biology, and neuroscience are interconnected. The books cover the same ground in very different styles.’ - from ‘Cosmology: A story of cosmic proportions,’ *Nature*. (Turner, 2015)

‘One was Barney Oliver. Tall, with an easy smile and manner, he enjoyed scotch and storytelling. Oliver’s easy going nature concealed an intense intellect,’ and ‘He was Shannon’s mirror image in his thin figure and height—and in his tendency to become

quickly bored of anything that didn't intensely hold his interest. This extended to people. "It was quite common for Pierce to suddenly enter or leave a conversation or a meal halfway through," wrote Jon Gertner.' - from 'How Information Got Re-Invented,' Nautilus. (Goodman, 2017)

By using and adding those narrative elements to the science stories, writers can learn easily integrating narrative elements into their science reporting. Each of the tools its own function and can be applied if there is a need to compare, retell, or describe a concept in an interesting way. The main function of science communication is appealingly communicating science ideas without sacrificing the quality, and integration of those tools can help serve that purpose, making science more integrated to people's living and understanding of the world.

7. Summary

Science storytelling journals used similar patterns and ideas to the ones used by another journal, but scientific narrative also had peculiarities that differentiated it from others. Science communication stories differ from other ones because they need to serve to be useful and communicate scientific information accurately and compellingly and interesting.

The same goal united all the journals - their mission was to educate the public about matters of science. Storytelling was a common way of presenting the ideas for all of the papers. But in each of the journals selected for the analysis, narrative structure occupied a different place. The fact that all of the most popular and credible science journals integrated storytelling in its reporting can also mean that science communicators have recognized the importance of stories in the process, even if that takes an extra effort.

The magazines approached the matter differently, and there were similarities and differences in the way they choose to report those stories. What united all of the publications is their interest in science communication and the willingness to go that extra step to create a story. All of the magazines selected for the analysis also used similar formatting, had paper and digital versions, and selective monetization of its content. But journals also had a noticeable difference, which resulted out of different historical contexts, readership, publication standards, goals, and priorities. These factors influenced the way they used storytelling in their reporting. The difference between papers can be analyzed based on the narrative structure preferences and use of literary tools.

All the publication used a three-act narrative structure in their stories, though they applied the structure differently. Considering that Nautilus and National Geographic are the journals that focus on the storytelling the most in their regular reporting, they also had a similar readership that can be identified as amateur science enthusiasts. For that reason, these two magazines similarly approached storytelling. Their stories had a similar character, scientists in their stories were often glorified, and articles had a sense of closure. Since the main focus of the Natulius is communication of sciences through storytelling, the magazine focused on describing scientific ideas through the use of narrative. National Geographic has a wider scope both in its readership and coverage of the topics, so it foused less on the science of things, and mainly reported on the stories from the world of science. In general, both of those journals focused on entertaining and enlightened the reader, rather than teaching, and making him question the ideas.

The practical and more analytical view on the sciences which was less entertaining, and more practical was the main focus of stories from Nature and Science. The main audience of those journals is scientists and researchers. For that reason, the magazine focused more on

delivering stories that would have interesting to researchers, and those practicing scientists would find useful. The topics they covered were more specific, and they presented focused more on the research insights but research. They used storytelling to report on those findings engagingly. The narratives were told from the perspective of scientists and focused more on the appreciation of researchers' lives, giving inside perspectives. With little to no advertisement, and almost no push of the subscription, the magazine's main focus was not readership, but the creation of accurate perspective on science. Scientific American has different standards for its articles, especially concerning the readership. The magazine is more news-oriented than other magazines and is intended for an even wider audience. Unlike other journals, want to appeal to appeal to the viral nature of the Internet. That reflected on the content of the stories they produced. Scientific American constructed its narratives more simplistically. They had simple heroes, conflicts, and predictable resolutions. The science in those articles was not detailed and was not integrated into the presented storyline. It might be the consequence of the times writers are given to write those stories - even though finding an article from the magazine that had a storytelling structure was difficult, the daily scope of the newspaper is much larger than that of the others. The magazine's priority is to deliver stories fast, so it has written more stories more quickly and makes the construction of the more compelling less buzzy. For context, as was mentioned in the content analysis Nautilus writers get six months for each piece they write. Scientific American posts ten stories every day. For that reason, the paper preferred simpler storytelling structures.

Besides the usage of the hero, conflict, and resolution narrative structure, the journals also told those stories differently and at the heart of those differences laid the usage of language and literary tools. The literary tools were used to enhance some aspects of the story and dictate

the storytelling language. Some of the magazines used more literary language and elaborate literary devices, like *Science* and *Nautilus*. Those journals integrate scientific concepts in the body of the text without separating it from the story, and that required more attention to the language used in the text. For that integration to occur smoothly, more in-text transformation was necessary and the writers for those journals have done it by using more metaphors, humor, and animation in their stories. *National Geographic*, though being a more storytelling-oriented journal than the others, in its articles often choose one type of literary trope, like humor and metaphor, and kept referring to throughout the text. In the case of *National Geographic*, it was easier to do that than with other journals, because the magazine did not need to focus on the integration of scientific ideas to the articles.

Articles in *Nature* and *Scientific American* used literary trope minimal. The articles in the magazine were less interested in complicated storylines, with *Nature*'s priority being factual reporting and the *Scientific American*'s reporting on the news in from the world of science. These publications used storytelling as a way of setting a background to the description of science in the body of the text. They rarely used literary devices, mainly employing them in the storylines.

Overall, even though *Nautilus*, *Science*, *Nature*, *Scientific American*, and *National Geographic* all used storytelling and different literary tools in their writings, the core mission behind the format was employed by all of them. This illustrates that the storytelling format is the one that needs to be employed in sciences and as long as the form is used, the format of the communication can be defined by the unique features of each publication. Science journals should be encouraged to employ and develop narrative tools in their communication because storytelling in science communication has an important role.

8. Limitations

It is important to acknowledge that the project had many limitations. It does not provide a definitive look at the entire field of science communication, and it has only covered a small area of it, limited to five science communication journals. A couple of limitations that is important to address to improve and contribute to the future field of research are a small sample size of the articles, selection process, and coding.

The first limitation is the sample size with which the the research. If the sample of the research is large, the conclusions are also more definitive and accurate. This analysis has been done only on the 40 articles picked from five different journals, which can help to form some conclusions. But by having more articles from more different kinds of science journals - like popular science journals, news publication, academic journals, university magazines, science magazines - the study would have helped to identify more patterns of storytelling and thus draw a picture that would reflect the current state of science communication more definitively. The larger sample would have also allowed forming guidelines and recommendations for science communication writers of the future. For the future studies, it would have been useful to look for more journals and articles that told stories, to ensure the conclusions were more objective and reliable.

The other thing that limited the effectivity of the research is the selection process and the coding process itself. These two steps were conducted manually and were based on the subjective decisions, mainly relying on my judgments and speculations. Even though the selection process of the journal included background checks and analysis of many credibility metrics, the same cannot be said about the articles themselves. Due to the limitations of the search capabilities within websites, the search for stories with storytelling was done manually through the usage of

the key phrases all over the website's page. It also means that the research was limited by my imagination and understanding of the storytelling structure as well as intuitive guesses about key terms used to tell stories. Even though the set mark of 8 articles per journal has been hit in all the cases, with some, it happened easier than with others, but definitive conclusions about that still cannot be drawn. If the process was randomized and, automated, better statistical conclusions could have been reached. To make the sample more objective for the future, it might be useful to select 100 recent articles from each journal and then look for narrative markers within them. In that way, the researchers can get data about how often the magazine use the structure in comparison with other publication. It would better reflect the state of science communication than the study has managed to do now.

The other limitation was in the literary analysis of the magazines. It came from my lack of in-depth knowledge of the field. The literature review of narrative structures used in storytelling has not been conducted, so the understanding of literary narrative was limited to my experience with the subject. It is possible that I could have missed some interesting tropes when reading and coding articles due to my lack of expertise. The better and larger literary framework would have helped to develop a better theory for this paper. It would have helped to draw a more accurate picture of the storytelling in science communication and develop better guidelines.

The study also can have a promising application in the field of education. For the personal usage, I have recorded how easy it was to read and understand subjects presented in the texts, but the data is too subjective to be valuable. However, researchers can elaborate on that idea, and compare effectivity of journal's storytelling based on a larger sample of people. That kind of social and media study might help to make use of narrative in science communication a standard.

The limitations that underlined all the other though were the lack of time resources and experiences. It ended up being a been small-scale research that helped to identify only some patterns of science communication used by popular science publication, but the study is not definitive. In the end, science communication is a relatively new and growing field of research that still can offer many areas of exploration.

9. References

Primary Sources

Carrie Arnold, N. (2017). The Mathematicians Who Want to Save Democracy. Retrieved from

<https://www.scientificamerican.com/article/the-mathematicians-who-want-to-save-democracy/>

Castelvecchi, D. (2018). Beguiling dark-matter signal persists 20 years on. Retrieved from

<https://www.nature.com/articles/d41586-018-03991-y>

Cohen, J. (2016). One of our reporters tried to do CRISPR. He failed miserably. Retrieved from

<http://www.sciencemag.org/news/2016/11/one-our-reporters-tried-do-crispr-he-failed-miserably>

Couzin-Frankel, J. (2016). Ailing fetuses to be treated with stem cells. Retrieved from

<http://www.sciencemag.org/news/2016/04/ailing-fetuses-be-treated-stem-cells>

Davies, S. (2015). Encounters with the Posthuman. Retrieved from [http://nautil.us/issue/1/what-](http://nautil.us/issue/1/what-makes-you-so-special/encounters-with-the-posthuman)

[makes-you-so-special/encounters-with-the-posthuman](http://nautil.us/issue/1/what-makes-you-so-special/encounters-with-the-posthuman)

Dolgin, E. (2017). Genetics: The hexanucleotide hex. Retrieved from

<https://www.nature.com/articles/550S106a>

Drake, N. (2016). NASA's Juno Spacecraft Is Now Orbiting Jupiter. Retrieved from

<https://news.nationalgeographic.com/2016/07/nasa-juno-mission-jupiter-arrives-orbit-planets-space/>

Drake, N. (2018). Meet the Crews Preparing for Human Life on Mars. Retrieved from

<https://www.nationalgeographic.com/photography/proof/2018/05/mars-on-earth-nasa-training/>

Gefter, A. (2015). Quantum Mechanics Is Putting Human Identity on Trial. Retrieved from

<http://nautil.us/issue/30/identity/quantum-mechanics-is-putting-human-identity-on-trial>

Gefter, A. (2015). The Man Who Tried to Redeem the World with Logic. Retrieved from

<http://nautil.us/issue/21/information/the-man-who-tried-to-redeem-the-world-with-logic>

Gibbens, S. (2017). In Unprecedented Loss, Endangered Whales Die of Mysterious Cause.

Retrieved from <https://news.nationalgeographic.com/2017/06/north-atlantic-right-whale-deaths-st-lawrence-sp/>

Gibney, E. (2018). How to blow up a star. Retrieved from

<https://www.nature.com/articles/d41586-018-04601-7>

Glionna, J. (2017). Brain Hackers Seeking Peak Performance Use Risky Chemical Cocktails.

Retrieved from <https://www.scientificamerican.com/article/brain-hackers-seeking-peak-performance-use-risky-chemical-cocktails/>

Goodman, J. (2017). How Information Got Re-Invented. Retrieved from

http://nautil.us/issue/51/limits/how-information-got-re_invented

Greshko, M. (2017). This Is the Best Dinosaur Fossil of Its Kind Ever Found. Retrieved from

<https://www.nationalgeographic.com/magazine/2017/06/dinosaur-nodosaur-fossil-discovery/>

Hand, E. (2015). How Pluto's most spectacular image was made—and nearly lost. Retrieved

from <http://www.sciencemag.org/news/2015/07/how-plutos-most-spectacular-image-was-made-and-nearly-lost>

Heinicke, C. (2018). My Year on "Mars." Retrieved from

<https://www.scientificamerican.com/article/my-year-on-mars/>

Keim, B. (2016). What Pigeons Teach Us About Love. Retrieved from

<http://nautil.us/issue/33/attraction/what-pigeons-teach-us-about-love>

Konnikova, M. (2017). Fiction: The science in Sherlock Holmes. Retrieved from

<https://www.nature.com/articles/549332a>

Krulwich, R. (2015). An 80-Year-Old Prank Revealed, Hiding in the Periodic Table!. Retrieved

from http://phenomena.nationalgeographic.com/2015/11/23/an-80-year-old-prank-is-revealed-hiding-in-the-periodic-table/?_ga=2.171010789.412338378.1518420548-2109233414.1517093192

Krulwich, R. (2016). Does the Loneliest Plant in the World Need Help?. Retrieved from

<http://phenomena.nationalgeographic.com/2016/02/01/does-the-loneliest-plant-in-the-world-need-help/>

Kupferschmidt, K. (2018). Seventeen volunteers let this worm live inside them to help defeat a dangerous disease. Retrieved from <http://www.sciencemag.org/news/2018/02/seventeen-volunteers-let-worm-live-inside-them-help-defeat-dangerous-disease>

Kucharski, A. (2014). Math's Beautiful Monsters. Retrieved from <http://nautil.us/issue/11/light/maths-beautiful-monsters>

Marshall, E. (2014). Dare to Do Less. Retrieved from <http://science.sciencemag.org/content/343/6178/1454/tab-pdf>

Maxmen, A. (2018). As Cape Town water crisis deepens, scientists prepare for 'Day Zero'. Retrieved from <https://www.nature.com/articles/d41586-018-01134-x>

Mirsky, S. (2018). Intelligent Aliens May Know about Us Well before We Find Out about Them. Retrieved from <https://www.scientificamerican.com/article/intelligent-aliens-may-know-about-us-well-before-we-find-out-about-them/>

Moskowitz, C. (2017). The Neutrino Puzzle. Scientific American. Retrieved from <https://www.scientificamerican.com/article/the-neutrino-puzzle/>

Mullard, A. (2017). The drug-maker's guide to the galaxy. Retrieved from <https://www.nature.com/news/the-drug-maker-s-guide-to-the-galaxy-1.22683>

Pappas, S. (2017). 280-Million-Year-Old Fossil Forest Discovered in Antarctica. Retrieved from <https://www.scientificamerican.com/article/280-million-year-old-fossil-forest-discovered-in-antarctica/>

Pennisi, E. (2018). Changes in gene activity may one day reveal the time of death for crime victims. Retrieved from <http://www.sciencemag.org/news/2018/02/changes-gene-activity-may-one-day-reveal-time-death-crime-victims>

Rupp, R. (2016). Jam: Chemistry and Cool in a Jar. Retrieved from

<https://www.nationalgeographic.com/people-and-culture/food/the-plate/2016/08/jam/>

Service, R. (2016). This protein is mutated in half of all cancers. New drugs aim to fix it before it's too late. Retrieved from <http://www.sciencemag.org/news/2016/10/protein-mutated-half-all-cancers-new-drugs-aim-fix-it-it-s-too-late>

Shraddha Chakradhar, N. (2018). A Private Place Where HIV, Zika and Ebola Hide. Retrieved from <https://www.scientificamerican.com/article/a-private-place-where-hiv-zika-and-ebola-hide/>

Skibba, R. (2018). Olympic Big Air Snowboarders Use Physics to Their Advantage. Retrieved from <https://www.scientificamerican.com/article/olympic-big-air-snowboarders-use-physics-to-their-advantage/>

Turner, M. (2015). Cosmology: A story of cosmic proportions. Retrieved from <https://www.nature.com/articles/526040a>

Voosen, P. (2017). Mars rover steps up hunt for molecular signs of life. Retrieved from <http://www.sciencemag.org/news/2017/02/mars-rover-steps-hunt-molecular-signs-life>

Waldrop, M. (2017). Einstein's Relativity Explained in 4 Simple Steps. Retrieved from https://news.nationalgeographic.com/2017/05/einstein-relativity-thought-experiment-train-lightning-genius/?_ga=2.171722469.412338378.1518420548-2109233414.1517093192

Weinstein, J. (2016). The Astrophysicists Who Faked It. Retrieved from <http://nautil.us/issue/42/fakes/the-cosmologists-who-faked-it>

Worth, T. (2017). Theatre: The bladder's tale. Retrieved from <https://www.nature.com/articles/551S42a>

Secondary Sources

AAAS. (2015). *Science Media Kit*. Retrieved from http://www.sciencemag.org/site/help/advertisers/2015_Media_Kit-Product_Advertising.pdf

AAM: Total Circ for Consumer Magazines. (2017). Retrieved from <http://abcas3.auditedmedia.com/ecirc/magtitlesearch.asp>

About Scientific American. Retrieved from <https://www.scientificamerican.com/page/about-scientific-american/>

Barnett, M., Wagner, H., Gatling, A., Anderson, J., Houle, M., & Kafka, A. (2006). The Impact of Science Fiction Film on Student Understanding of Science. *Journal of Science Education and Technology*, 15(2), 179-191. Retrieved from <http://www.jstor.org/stable/40186682>

Bilton, R. (2016). A cross-disciplinary approach to science is helping Nautilus carve a unique niche in science publishing. Retrieved from <http://www.niemanlab.org/2016/09/a-cross->

disciplinary-approach-to-science-is-helping-nautilus-carve-a-unique-niche-in-science-publishing/

Clarivate Analytics. (2017). *Journal Citation Reports*. Retrieved from

http://images.info.science.thomsonreuters.biz/Web/ThomsonReutersScience/%7Bda895e0c-0d4f-44f2-a6d5-6548d983a79f%7D_M151_Crv_JCR_Full_Marketing_List_A4_FA.pdf

Djerassi, C. (1998). Ethical discourse by science-in-fiction. *Nature*, 393(6685), 511.

Downs, J. (2014). Prescriptive scientific narratives for communicating usable science.

Proceedings of the National Academy of Sciences of the United States of America, 111, 13627-13633. Retrieved from <http://www.jstor.org/stable/43043101>

Editorial criteria and processes | Nature. (2018). Retrieved from

<https://www.nature.com/nature/for-authors/editorial-criteria-and-processes>

Faculty of English. Retrieved from <https://www.english.cam.ac.uk/classroom/terms.htm>

Fersht, A. (2009). The most influential journals: Impact Factor and Eigenfactor. Retrieved from

<http://www.pnas.org/content/106/17/6883>

Fischhoff, B., & Scheufele, D. (2014). The Science of Science Communication II. *Proceedings of the National Academy of Sciences of the United States of America*, 111, 13583-13584.

Retrieved from <http://www.jstor.org/stable/43043094>

Foster, B. (2012). Evolution of National Geographic Magazine. Retrieved from

<http://press.nationalgeographic.com/files/2012/05/NGM-History-10-12.pdf>

Homepage : History of the Journal Nature. Retrieved from

<https://www.nature.com/nature/history/index.html>

Kulkarani, P. (2013). Rethinking "Science" Communication. *Issues In Science & Technology*, 30(1), 25-29.

Literary Devices. Retrieved from <http://literary-devices.com/>

Lucky, R. (2000). The Quickening of Science Communication. *Science*, 289(5477), 259-264.

Retrieved from <http://www.jstor.org/stable/3077575>

NationalGeographic.com. National Geographic Timeline. Retrieved from

<https://www.nationalgeographic.org/timeline/?locale=en>

Nautilus. (2017). *Nautilus Media Kit*. Retrieved from [http://nautilus-](http://nautilus-prod.s3.amazonaws.com/pdf/Nautilus_Media_Kit_Jan-2017.pdf)

[prod.s3.amazonaws.com/pdf/Nautilus_Media_Kit_Jan-2017.pdf](http://nautilus-prod.s3.amazonaws.com/pdf/Nautilus_Media_Kit_Jan-2017.pdf)

Noorden, R. (2013). Open access: The true cost of science publishing. Retrieved from

<https://www.nature.com/news/open-access-the-true-cost-of-science-publishing-1.12676>

Overbye, D. (2013). A Glossy Science Magazine or Living Fossil?. Retrieved from

<https://www.nytimes.com/2013/05/07/science/a-glossy-science-magazine-or-living-fossil.html>

Quirk, T. (2016). The Problem With Science Writing. *Nautilus*. Retrieved from

<http://nautil.us/blog/the-problem-with-science-writing>

Santora, M. (2005). Dennis Flanagan, 85, Longtime Editor of Scientific American, Dies.

Retrieved from <https://www.nytimes.com/2005/01/17/obituaries/dennis-flanagan-85-longtime-editor-of-scientific-american-dies.html>

Schulson, M., & Raeburn, P. (2017). Award-Winning Nautilus Magazine Enters Troubled

Waters. Retrieved from <https://undark.org/2017/04/29/award-winning-nautilus-enters-rough-waters/>

Scientific American. Retrieved from

<https://www.nature.com/scientificamerican/information/aims.html>

Springer Nature. (2018). *Nature Media Kit*. Retrieved from <https://partnerships.nature.com/wp-content/uploads/2017/10/Nature-Research-Life-Physical-Sciences-Media-Kit-2018-1.pdf>

Sugimoto, C. R., Thelwall, M., Larivière, V., Tsou, A., Mongeon, P., & Macaluso, B. (2013).

Scientists Popularizing Science: Characteristics and Impact of TED Talk Presenters. *Plos ONE*, 8(4), 1-8. doi:10.1371/journal.pone.0062403