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National parks as vehicles for science communication: the science of signs

Lloyd S. Davis, Lei Zhu and Wiebke Finkler

Abstract

Signs used for science interpretation within national parks have been little studied. We analyzed the textual content of 129 signs in 11 US national parks. Science content was high, but readability was low overall and inversely related to the amount of science content. The amount of science varied by subject area and national park, as did the depth of information and its relevance to humans. Colorado's Great Sand Dunes National Park, however, had signs containing high amounts of science with the highest readability scores, emphasizing the potential benefits for science communication that can come from understanding the science of signs.

Keywords

Environmental communication; Public engagement with science and technology; Science writing

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1 ▪ Introduction

Interpretive signage is a widely used means to communicate information, including science, in outdoor natural environments. Effective interpretation through signage may enrich visitors' experiences, expand their knowledge and enhance their awareness of environmental issues [Colquhoun, 2005; Ham & Weiler, 2007; Ismail, 2008]. However, shortcomings in the content of signage and its interpretation can also negatively impact visitor experiences [Ababneh, 2017]: e.g., adequate signage has been identified as a key factor mitigating visitor dissatisfaction in Canadian national parks [Zolfaghari & Choi, 2023].

Research to date has focused on visitors' evaluations and impressions of signage at different natural sites [Clary & Wandersee, 2014; Davis & Thompson, 2011; Zhu et al., 2021a]. By contrast, there has been little research analyzing the actual content of existing signage, particularly in relation to the communication of science. A major issue, highlighted by Clary and Wandersee [2014], is that "*signage intended to educate a visitor may be above the visitor's reading level, contain too many science-specific words, and be too lengthy*". Textual complexity in the content of interpretive signage is a significant problem that limits the understanding and enjoyment of visitors [Wandersee & Clary, 2007] and, thereby, reduces the effectiveness of signage for the purposes of science communication [Burns et al., 2003].

Using quantitative content analysis of interpretive science signage with a focus on readability can provide: (i) development of criteria for assessing the quality of interpretive content, and (ii) identification of issues when designing and evaluating interpretive signage [Wandersee & Clary, 2007]. However, with the exception of a small number of signs evaluated at single sites [Wandersee & Clary, 2007], to date there has been no systematic study of the content of existing interpretive science signage.

1.1 ▪ *National parks as vehicles for science communication*

There are over 6,500 national parks in the world (https://iucn.org), which exist as specially protected areas that typically contain iconic natural features that may be geological, zoological, or botanical in nature. As such, they have the potential to be excellent vehicles for communicating science to the public that visits them [Finkler & Davis, 2022]. The iconic features within national parks act as "hooks", piquing the interest of a captive audience of visitors who have travelled to the parks specifically to see them [De Kryger, 2021] and are, therefore, receptive to learning about them, including the associated science [Zhu et al., 2021a].

National parks vary greatly, however, in the degree of interpretative material available for visitors [Thompson & Houseal, 2020]. The most common form of interpretation used in national parks involves signage [Bose et al., 2020]. While there have been studies that have examined factors that make signs more appealing and comprehensible for visitors in national parks — such as the inclusion of imagery [Wolf et al., 2013; Zhu et al., 2021b] — there have been no studies on the complexities of the language used in signage, even though it is well-established that the use of large words and jargon impair people's abilities to process scientific information [Bullock et al., 2019], even when definitions of the jargon terms are provided [Shulman et al., 2020]. When conveying science, the negative effects of jargon can be countered by the inclusion of explanatory infographics [Riggs et al., 2022], which are typically viewed as best practice in signage concerning safety in national parks in order to remove ambiguity [Saunders et al., 2019] although, even then, research has shown less than half of visitors interpret such signage correctly in naturalistic settings [Aucote et al., 2012]. Research indicates that educational messaging will be most effective when it is clear and succinct [Ham, 2016].

1.2 ▪ *Language complexity as a barrier to comprehension of science*

There is ample evidence, particularly from within educational contexts, that linguistic complexity negatively impacts comprehension of science [Arya et al., 2011]. There are a number of features of language that affect the perception of complexity, but two relevant to science comprehension include syntactic complexity (e.g., sentence structure and length) and lexical complexity (e.g., word structure) [O'Leary & Steinkrauss, 2022], with the latter being a characteristic of jargon words associated with science that are often multisyllabic and have various affixes added to their beginnings or endings [Gillet, 2025]. All this can affect the readability of signage, and more research is needed to better understand the use of wording and design of signage in national parks [Bose et al., 2020].

Content analysis provides an appropriate means to evaluate interpretive science signage in a systematic and quantitative way. In this study, we conducted an in-depth content analysis on the textual content of interpretive signage within 11 US national parks. The aim of the content analysis was to answer the following three research questions:

RQ1: How much science and what topics are communicated in interpretative signage in US national parks?

RQ2: How readable is the text used in interpretative signage in US national parks, and does it vary between subjects and national parks?

RQ3: Does the depth of information provided in signage vary according to the subject and to what extent does it include a human perspective to make it relevant to visitors?

2 ▪ Methods

2.1 ▪ *Sampling*

The 11 national parks used in this study were visited between 15 July 2018 and 25 June 2019. The parks and the abbreviations used for them in this paper are: Arches National Park (ARNP), Bryce Canyon National Park (BCNP), Black Canyon of the Gunnison National Park (BGNP), Canyonlands National Park (CANP), Capitol Reef National Park (CRNP), Grand Canyon National Park (GCNP), Great Sand Dunes National Park (GSNP), Hawaii Volcanoes National Park (HVNP), Petrified Forest National Park (PFNP), Rocky Mountain National Park (RMNP), and Zion National Park (ZINP).

The period for sampling signs consisted of two days at each national park. Sampling began at the visitor center inside the park's boundaries (note: sampling at GCNP occurred on the North Rim). One of us (LSD) then followed the guide maps provided at the visitor center to visit the recommended viewpoints possible to be accessed on foot or by automobile from the visitor center. Each sign encountered was measured and photographed using a 16-megapixel digital camera. The intention was not to be exhaustive (i.e., not to photograph *every* sign in the park), but instead to use all-occurrence sampling [Lehner, 1996] to photograph *all signs*

Figure 1. An interpretive sign at Petrified Forest National Park: an example of the standardized interpretive signs used in US national parks.

encountered, thereby mimicking the exposure to signage that might be experienced by a visitor to the park over a similar two-day period.

There are many different types of signs used in US national parks [Thompson & Houseal, 2020] and these vary in their size, shape and purpose: such as those used for maps, safety messages and warnings, information at trailheads, species identification of plants, photographs, and science interpretation. For the purposes of interpretation, there is, however, a standardized sign that is used in all the national parks visited. This consists of a rectangular sign that is approximately 62 cm in height by 93 cm in width, placed on four legs at an angle so that it can be read easily by a visitor looking down when standing before a vista to which the sign refers (Figure 1). Therefore, to compare the degree of science interpretation between the 11 national parks, the content of only the standardized interpretative signs is used in this paper (n = 129).

The JPEG files of the photographs of the signs were run through Prizmo 4 software, which used optical character recognition (OCR) to extract the text from the photographs. The extracted text was then manually checked against the photographs by one of us (LZ) and any errors corrected. Single words and phrases used in any of the infographics in the signage were excluded from the readability analysis, even though they were identified by the OCR, because readability scores are only meaningful within the context of full sentences.

2.2 ▪ *Subject analysis*

Most of the interpretative signage in the parks dealt with geological or biological topics. Accordingly, we divided the signs into three science subject groupings: Geology, Biology, and Other (which consisted of any signs covering sciences other than geology or biology).

Next, all the sentences in the textual content of each sampled sign were reviewed and classified as either those that referred to science or those that did not. We used these data to calculate the proportion of science sentences used in each sign as a measure of how much science was communicated in the signs. The average proportions of science sentences in signs were then compared by subject and across the different national parks. Word frequency analysis was conducted on the text in each sign using NVivo 12 to examine the specific topics interpreted under each subject.

2.3 ▪ *Readability*

The concept of readability is a vital indicator that can be used to measure the complexity of textual content in a quantitative way [Goldman & Lee, 2014]. Flesch [1948] developed the Flesch Reading Ease (FRE) as a measurement of readability, which has become the best-known and most commonly applied method for assessing readability [Barbic et al., 2015; Zhou et al., 2017]. A higher Flesch Reading Ease score means a tested passage is easier to read and vice versa. The score is calculated using the following formula:

$$206.835 - 1.015\left(\frac{\text{total words}}{\text{total sentences}}\right) - 84.6\left(\frac{\text{total syllables}}{\text{total words}}\right)$$

We measured the readability of signs using the Flesch Reading Ease score calculated by the website *Count Wordsworth* (http://countwordsworth.com/), which was an online tool for calculating Flesch Reading Ease scores based on the formula above (note: this service is no longer available). The text used for each calculation consisted of all the textual content in each of the interpretive science signs (captions for photographs on signs were not included). Average scores for all the sampled signs in each national park and those for each subject were then calculated and compared using SPSS Version 24.

Hartley [2016] criticized the Flesch Reading Ease score for not taking the context of content into account. We acknowledge this limitation so, to address this, we also analyzed the topic (what scientific topics were being communicated) and the level of interpretation (what depth did the science explanation go into).

2.4 ▪ *Levels of interpretation*

Levels of interpretation were measured using two dimensions: depth of information and human relevance. The depth of information was defined as a binomial variable: surface interpretation and depth interpretation, corresponding to different types of knowledge that visitors may acquire [Bennet & Bennet, 2008]. Specifically, surface interpretation merely presents science facts without any explanations, context or other details (e.g., traits and processes); whereas depth interpretation communicates science in a detailed way, giving explanations, evidence, context or other descriptions.

Table 1. Coding scheme (coding unit: sentence).

Dimensions	*Depth of information*	*Human relevance*
Code 1	Surface interpretation	Relevant to human
Code 2	Depth interpretation	Irrelevant to human

Modern science communication models suggest that the communication will be more effective if the science being communicated is relevant to the audience [Nisbet & Scheufele, 2009]. Some of the interpretative signs in the national parks referenced the relevance of the science for humans: e.g., when referring to topics such as air pollution and the potential conflict between tourists and wildlife [Chanie & Tesfaye, 2015; Keiser et al., 2018]. We used a similar binomial variable for human relevance, whereby content was scored as to whether the science content of the signs referred to humans or not.

The textual content in the sampled signage was coded according to these two dimensions of depth of interpretation and human relevance. Each dimension had two mutually exclusive codes (i.e., surface or depth interpretation; relevant or not relevant to humans, Table 1) [White & Marsh, 2006]. The units used for coding were sentences. After developing the coding manual, two researchers started the training process, which included coding the textual content from a set of randomly selected signs consisting of 20% of the total sampled signs [Liang et al., 2019]. We then calculated the inter-coder reliability (degree of agreement and Cohen's Kappa) and discussed the coding results where the two researchers were not in agreement. The coding scheme and ways of coding were slightly modified based on these discussions, then the researchers did the training again until the reliability reached the acceptable level of above 0.90 [Liang et al., 2019; Neuendorf & Kumar, 2016]. The final degree of agreement was 0.946 and the Cohen's Kappa was 0.918. We then completed coding the rest of the content (the remaining 80% of the total sampled signs).

NVivo Version 12 was used for the coding process. Frequencies of codes were grouped by the different national parks as well as subjects for subsequent statistical comparisons with SPSS Version 24.

3 ▪ Results

3.1 ▪ *Subject analysis*

The main subjects interpreted by the sampled signage were Geology (74 signs, 57.4% of the total 129 sampled signs) and Biology (41 signs, 31.8% of the total sample). Other science topics (10.9%) that did not fall into the above two subjects included climate, air quality, light pollution and environmentally friendly behaviours.

The subject areas covered by interpretative signage varied across the national parks (Figure 2). Arches National Park had more Geology signs (90.9%) than other national parks did, while the proportion of Biology signs within this park (9.1%) was the second-lowest amongst the 11 national parks. Similarly, interpretive signs in Petrified Forest National Park also focused on Geology (84.6% of the signage within this park) with biological topics comprising the lowest percentage of sampled signs within any of the parks (7.7%). By contrast, Rocky Mountain National Park contained the largest proportion of Biology signs

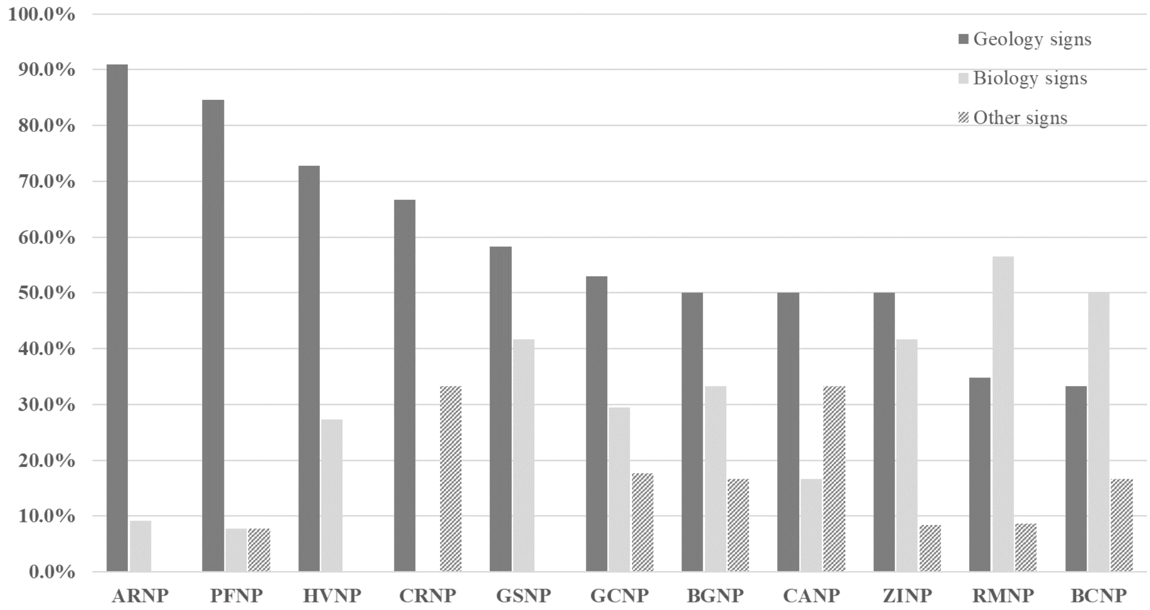

Figure 2. The percentage of interpretative signs by subject area (Geology, Biology, Other) in 11 US national parks.

Table 2. Word frequency analysis of interpretative signs in each subject group (Biology, Geology, Other) showing the six words with the highest frequency.

Biology	*Geology*	*Other*
Forest (58)	Rock (161)	Canyon (28)
Plant (53)	Canyon (104)	Air (23)
Fire (40)	Form (96)	View (16)
Tree (38)	River (75)	Park (16)
Soil (32)	Layer (75)	Water (15)
Animal (31)	Water (73)	Pollution (14)

(56.5%). Perhaps somewhat surprisingly, given that the iconic features of Bryce Canyon National Park are geological in nature, Biology was also the dominant subject (50%) in its interpretive signage. Canyonlands National Park had the largest proportion of signs (33.3%) that fell into the Other subject category, being neither geological nor biological in their scope.

The overall percentage of sentences containing science on all 129 interpretative signs was 79.2%. However, the percentage of sentences about science varied significantly according to the subject of the signage (Kruskal-Wallis Test, Chi-square $= 169.22$, $p < 0.001$). Signs about Biology had more science content (88.3% of sentences) than those about Geology (77.7%) or Other subjects (67.2%). Post-hoc pairwise comparisons showed that the differences were highly significant between any pair of subjects (Biology and Geology, Geology and Other, and Biology and Other, all p values < 0.001).

Results of word frequency analysis (Table 2) suggest that “forests” and “plants” are the most frequently interpreted topics for Biology signs. Three out of the six most recurring words in Biology signs referred to plants: “forest”, “plant” and “tree”. Geology signs were mainly focused on the formation of rock layers: “rock” being the most recurrent word, followed by "canyon", "form", and "layer" — all of which refer to different aspects of rocky landscapes. The other two most frequently repeated words on signs about Geology were "water" and "river", which are involved in landscape formation. For signs covering Other subjects, "air", "view", "water" and "pollution" were some of the most prominent words, which was in line with the most common topics interpreted by these signs being about pollution of the air or water within national parks.

3.2 ▪ *Readability*

The 129 science signs had an average Flesch Reading Ease (FRE) score of 51.19. FRE was significantly influenced by the subject area of signage (Kruskal-Wallis Test, Chi-square $= 61.46$, $p < 0.001$), with the readability of Biology signage (45.53) being significantly lower than signage about Geology (53.66) or Other subjects (53.55). Post-hoc comparisons showed that the poorer readability of signage about Biology compared to signage about Geology was highly significant ($p < 0.001$), as it was for the comparison of signage about Biology and Other topics as well ($p < 0.001$). However, there was no significant difference in the readability of signage dealing with Geology or Other subjects ($p = 0.58$).

The readability of interpretative signage varied significantly across national parks (Kruskal-Wallis Test, Chi-square $= 141.97$, $p < 0.001$, Figure 3). The Flesch Reading Ease score was negatively correlated with the proportion of science in signs (Pearson's $r = -0.535$, $p < 0.001$). For example, interpretative signs within Zion National Park, which had the highest proportion of science sentences for any of the sampled national parks, had the lowest readability scores (44.13), while those in Capitol Reef National Park, with the second-lowest proportion of science sentences had the second-highest readability scores (54.78). However, incorporating science into signage need not be associated with low readability: interpretative signage in Great Sand Dunes National Park had the highest readability score of all the national parks (56.40), yet the percentage of sentences devoted to science in the signage (83.7%) was above average for the signage sampled across all the national parks (79.2%). This means high readability and a high proportion of science content may coexist.

3.3 ▪ *Levels of interpretation*

The national park significantly influenced the levels of interpretive content in signage in terms of both the depth of information (Chi-square $= 38.78$, $p < 0.001$) and human relevance (Chi-square $= 47.65$, $p < 0.001$). Rocky Mountain National Park (RMNP) stands out as the park in which the signage has both the greatest depth of interpretation and the most human-related content (Figure 4).

With respect to the subject interpreted, signs about Biology (Table 3) provided more depth interpretation than did signage about Geology or Other subjects (Chi-square $= 23.33$, $p < 0.001$). The percentages of human-related sentences were also significantly different across the three subject areas (Chi-square $= 194.54$, $p < 0.001$). Specifically, signs about Other subjects contained the highest percentage of human-related content, while Geology signage had the least percentage of such content.

Signs about Biology presented a significantly larger proportion of in-depth content (depth interpretation) than did signs about Geology or Other subjects (z tests for multiple

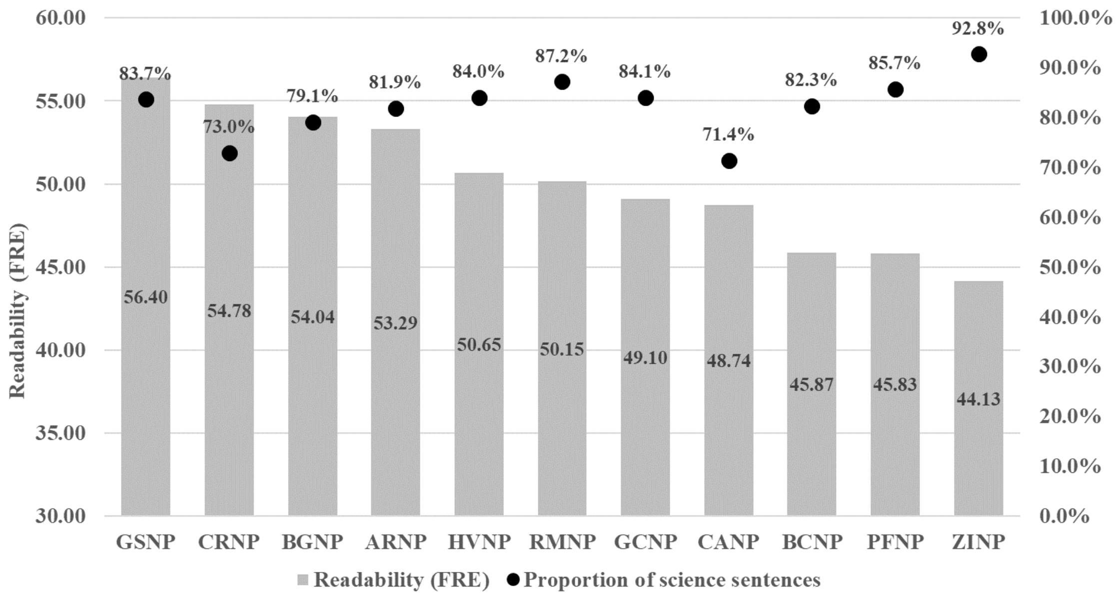

Figure 3. Average readability (Flesch Reading Ease score, FRE) and the average percentage of sentences containing science for interpretative signage in 11 US national parks.

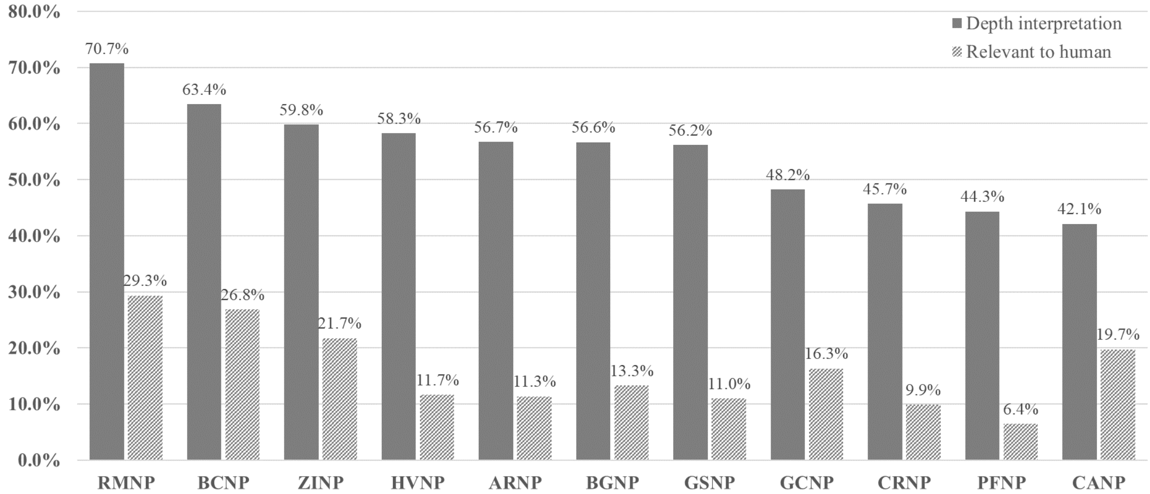

Figure 4. Percentage of sentences in signs providing deep levels of science interpretation and relevance to humans for interpretative signage in 11 US national parks.

comparisons after chi-square test: $p < 0.001$ between Biology and Geology signs, and $p < 0.01$ between Biology and Other signs). In other words, compared with signs about Biology, those about Geology and Other subjects provided more surface-level interpretation.

Signs about Geology contained the smallest proportion of interpretation related to humans, while those about Biology had more human-related stories. Yet, signage about subjects Other than Biology or Geology had the largest proportion of human-related content. Multiple comparisons (z tests after the Chi-square test) show there were significantly different proportions between all the three subject groups ($p < 0.001$).

Table 3. Percentages of codes for depth of information (a) and human relevance (b).

Codes *(Depth of information)*	*Geology* (n = 74)	*Biology* (n = 40)	*Other* (n = 15)
Depth interpretation	50.2%	65.8%	51.7%
Surface interpretation	49.8%	34.2%	48.3%

(a)

Codes *(Human relevance)*	*Geology* (n = 74)	*Biology* (n = 40)	*Other* (n = 15)
Relevance to humans	4.5%	24.3%	48.3%
No relevance to humans	95.5%	75.7%	51.7%

(b)

4 ▪ Discussion

Nature-based tourism, especially in national parks, is one of the fastest growing sectors of the tourism industry [Raasch, 2004]. This also represents an enormous opportunity for science communication and education within national parks [Finkler et al., 2021; Thompson & Houseal, 2020]. Our study of interpretative science signage in 11 national parks in the United States revealed a variable, albeit modest, number of interpretative signs encountered within a two-day visit to all the national parks.

4.1 ▪ *RQ1*

In relation to RQ1, the percentage of science sentences in such signs was remarkably high, with four of every five sentences containing some aspect of science. Perhaps unsurprisingly, the nature of the science subject areas covered in the signs varied according to the national park and the iconic features for which it is primarily known. More than two-thirds of the signage in Arches National Park, Petrified Forest National Park, Hawaii Volcanoes National Park, and Capitol Reef National Park — all areas known for their geological features — are about Geology. Even so, Geology accounted for at least a third of all interpretative signage in every national park, suggesting that the permanent and expansive properties of geological formations make them especially conducive to interpretative signage at viewing points within national parks. Biology, by contrast, was less represented than Geology in nearly all the national parks. Additionally, word frequency analysis showed forests and plants are the topics most frequently covered by signs about Biology. This suggests that it is the immovable characteristic of trees and plants, akin to that of geological formations, that makes them suitable for interpretative science signage. In comparison, the movements of mobile animals are harder to predict in space and time so that placement of signage becomes an issue if the subject (or evidence of it) cannot be seen from the vantage point of the sign. An exception is Rocky Mountain National Park, where the distribution of animals like elk, ground squirrels, moose and butterflies can be mapped quite closely to discrete areas, encouraging placement of corresponding signage. This was the only national park where signs about Biology accounted for more than half the interpretative signage in the park.

4.2 ▪ *RQ2*

Readability of interpretative signage did indeed vary across both national parks and subject areas (RQ2), with the amount of science in the signs being inversely related to the readability score. This fits with what is known from other studies of education and science, where science is perceived to be dense and therefore intractable for many people [Finkler et al., 2021]. However, as seen at Great Sand Dunes National Park (GSNP), it is possible to have relatively high readability scores and still have a relatively large amount of science content. The characteristic that most influenced the readability score for GSNP was the low frequency of large or jargon words, which can make science seem difficult to many laypersons [Bullock et al., 2019].

Be that as it may, the signs of even the six national parks with the highest readability scores, which ranged from 50.15 to 56.40 (Figure 3), represent text that would be "fairly difficult" to read, requiring a reading grade corresponding to 10^{th}–12^{th} grade and, therefore, likely to be fully understood by only just over half of the US adult population [DuBay, 2004 cited in Heydari, 2012]. Hence, the overall readability scores of the interpretative signs in the 11 national parks were quite low, meaning that many visitors would be likely to struggle to make sense of them [O'Leary & Steinkrauss, 2022]. This suggests improvements to the readability and attractiveness of signs in national parks should be made by using better design and supplementing the textual information with infographics [Rodríguez Estrada & Davis, 2015], as well as making them more inviting by using colourful imagery [Zhu et al., 2021a, 2021b], and leveraging techniques derived from science communication research that have been demonstrated to improve comprehension, such as storytelling and humour [Davis et al., 2018].

4.3 ▪ *RQ3*

Signs about Biology went into the most depth regarding the level of science being interpreted but, likely as a consequence, Biology signs had the lowest readability scores. Again, this suggests that simply throwing more information at visitors is unlikely to be the best way of doing interpretation. Making stories and especially those that show some relevance to the visitor (i.e., human-related stories) may well make interpretative signage more attractive and useful to visitors [Stoffle et al., 2020].

4.4 ▪ *Directions for future research*

The next steps to further this research require a two-pronged approach: (i) more surveys of visitors to national parks to directly measure their levels of satisfaction, comprehension and knowledge gained from reading existing signage, similar to those carried out by Zhu et al. [2021a, 2021b] in Chinese national parks, and (ii) test different means of improving the communication of science in national parks, such as the use of smaller words with less jargon [Bullock et al., 2019], colourful hero images [Zhu et al., 2021a], the incorporation of storytelling [Davis & León, 2018] and opportunities for interaction [Juma et al., 2020].

National parks hold great promise for encouraging visitors to learn about science and the features of the world around us. We need to find the best cost-effective and most rewarding ways of doing that. Signage has the potential to do all that if we can make the design of interpretative signs better. This study provides a benchmark against which to measure our progress and understanding of the science of signs.

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About the authors

Lloyd S. Davis: Stuart Professor of Science Communication, University of Otago. Particularly interested in the role that storytelling can play in enhancing science communication.

lloyd.davis@otago.ac.nz

Lei Zhu: Researcher, University of Otago Library. Strong research interests in using imagery, especially photography, as a means of supplementing science communication.

s.villosa@gmail.com

Wiebke Finkler: Senior Lecturer, Department of Marketing, University of Otago. Specialising in behaviour change communication for social good and conservation.

wiebke.finkler@otago.ac.nz

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