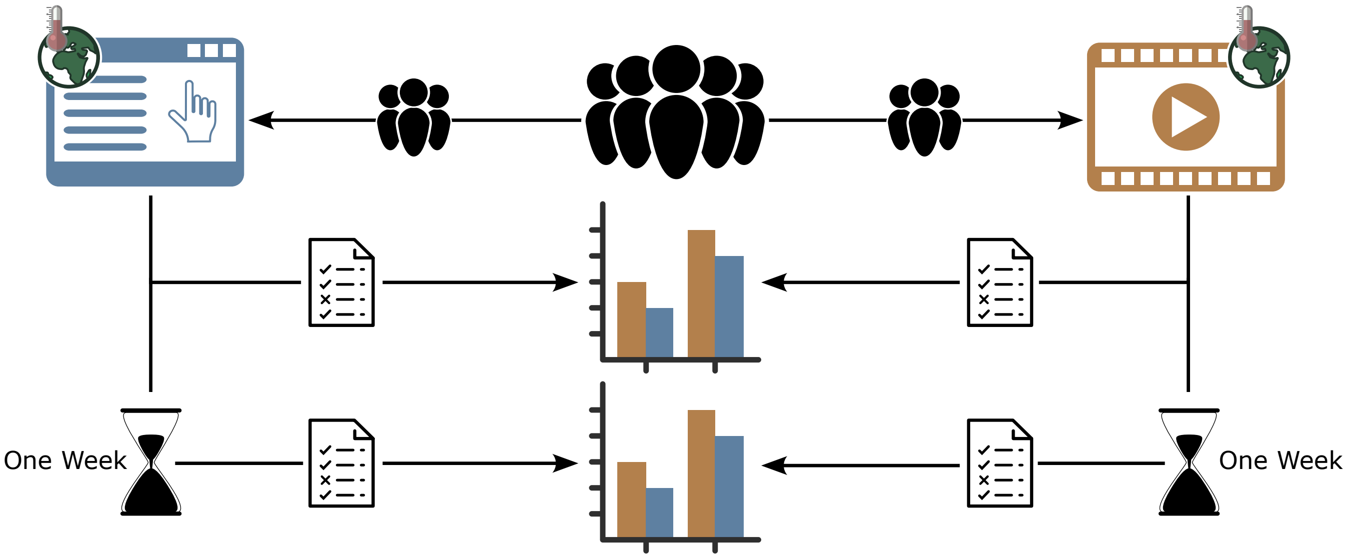
Eurographics Conference on Visualization (EuroVis) 2025
W. Aigner, N. Andrienko, and B. Wang
(Guest Editors)

COMPUTER GRAPHICS *forum*
Volume 44 (2025), Number 3

Either Or: Interactive Articles or Videos for Climate Science Communication

J. Poehls[1], M. Meuschke[2], N. Carvalhais[1], K. Lawonn[3]

[1]Max Planck Institute for Biogeochemistry, Department of Biogeochemical Integration, Germany
[2]University of Magdeburg, Department of Simulation and Graphics, Germany
[3]University of Jena, Institute of Computer Science, Germany



Abstract

Effective communication of climate science is critical as climate-related disasters become more frequent and severe. Translating complex information, such as uncertainties in climate model predictions, into formats accessible to diverse audiences is key to informed decision-making and public engagement. This study investigates how different teaching formats can enhance understanding of these uncertainties. This study compares two multimodal strategies: (1) a text-image format with interactive components and (2) an explainer video combining dynamic visuals with narration. Participants' immediate and delayed retention (one week) and engagement are assessed to determine which format offers greater saliency.

Sample analysis ($n = 622$) displayed equivalent retention by viewers between both formats. Metrics assessing interactivity found no correlation between interactivity and information retention. However, a stark contrast was observed in the time viewers spent engaging with each format. The video format was 29% more efficient with information taught over a period of time vs. the article. Additionally, retention on the video format worsened with age ($P = 0.004$) while retention on the article format improved with education ($P = 0.038$). These results align with previous findings in literature.

1. Introduction

As climate-related disasters become more frequent, the need to effectively communicate potential risks and future impacts to a broad audience is increasingly urgent. It is essential to convey complex information, such as the uncertainties in climate predictions, to both the general public and policymakers who may not have extensive scientific backgrounds. Clear communication of such uncertainties can lead to more informed decision-making, especially when it comes to public safety and research funding, as was demonstrated during the COVID-19 pandemic.

In response to this challenge, we conducted a study to explore how different multimodal learning approaches can improve the communication of complex climate science, particularly the uncertainties in climate predictions derived from Earth system models. Multimodal learning leverages the use of multiple learning modalities—such as visual, auditory, reading/writing, and kinesthetic modalities—to enhance understanding. While individuals may have preferences for certain modalities, research shows that combining two or more modalities, known as multimodal learning, generally leads to better comprehension [CD18]. This benefit is largely attributed to the concept of dual coding, where different parts of the brain process different types of information, creating multiple cognitive pathways for learning [CP91].

Our study specifically compares two multimodal approaches: (1) a text-image format paired with interactive components that illustrate key concepts, and (2) an explainer video that combines visual representations with narration. We aim to determine which method better facilitates understanding and retention of information. By analyzing participants' information retention and the time spent engaging with each format, we assess which approach is more effective at conveying these scientific uncertainties to a diverse audience. Ultimately, this research seeks to answer the question: Which of these two multimodal learning strategies is more effective in helping people understand and retain complex climate science concepts, particularly uncertainties in climate models?

2. Related Work

This section examines dual coding and narrative visualization, reviewing studies on the teaching effectiveness of audiovisual formats (e.g., videos) and illustrated text, highlighting mixed findings. It also explores how interactivity influences engagement, comprehension, and recall, identifying a gap in comparing interactive and illustrated articles with video formats.

2.1. Dual Coding

There have been a few studies over the years comparing the effectiveness of different dual-coding learning styles. The two primary approaches are either audiovisual - usually in the form of a video - and illustrated text - in the form of articles with descriptive pictures. These studies provide conflicting results but recently have been trending towards the effectiveness of video formats for new learners.

Text Outperforms Video

The most cited work concerning this particular question determined that static images with accompanied text displayed "significantly better" performance compared to those who watched a narrated animation [MHMC05]. Additionally, students tasked with studying and comprehending a topic performed better when using texts [LB19]. This stemmed from the ease of students' ability to quickly find and verify information in text, whereas those with the video had to rewind/replay sections to access the information. These studies demonstrate a text advantage over video.

Text is Similar to Video

A few studies find little to no difference in performance - with some caveats. Text-based learners believed their comprehension of a topic was greater than their video counterparts despite similar performance [KHS22]. Although findings suggest immediate retention was similar, a study found that after one day, those exposed to the illustrated text format had better recall [VSV14]. Brain imaging during an exam revealed that audiovisual formats activated more brain regions, particularly the prefrontal cortex [PBM*19]. This region is associated with higher-level cognitive functions and indicates the information is being processed differently. Unfortunately, the authors did not conduct a delayed information retention study. These studies demonstrate that any differences in learning were minimal.

Video Outperforms Text

There are a handful of studies that find the audiovisual format to be advantageous. Video learners in a school setting outperformed text counterparts on information transfer, retention, and delayed retention after seven days [HJL23]. Researchers also found an 8 % increase in information retention compared to text [Sch20]. A meta-analysis of instructional videos found that videos "significantly enhance learning effectiveness" when videos are presented in the classroom, whereas videos outside of the classroom have no significant impact on retention [LZ23]. The same study also found that videos benefited primary and middle schoolers and decreased with education. This seems to align with the findings of List et al. [LB19] as videos are less practical for study than text due to difficult information access. The authors suggest this negative correlation with education is due to undergraduates requiring analytical and rational thinking of familiar topics, whereas videos often present direct and simplified information for those unfamiliar with a topic. A systematic review of video learning found a mild benefit when video replaced learning materials (Hedges $g = 0.28$) and a very strong benefit when videos supplemented learning materials ($g = 0.80$) [NGD*21]. This analysis does not directly compare video against illustrated text. Instead, it simply highlights the potential benefits of the video format.

Videos also hold an advantage with regard to engagement. Good science communication conveys topics to those who are not typically seeking out that type of information. It has been observed that, regardless of information retention, videos hold the attention and engage viewers/learners with greater efficacy compared to illustrated text [CSW99; YPL*11; LLC*21; MVHS15], with youths prioritizing video sources over text-based formats when given the opportunity [DK22]. These findings highlight the advantages of the video format for communication outreach.

2.2. Narrative Visualization

Narrative visualization has emerged as a crucial intersection between data visualization and storytelling, combining analytical rigor with engaging narrative elements to effectively communicate insights to broad audiences. It has been applied across various fields, including medicine [MGS*22; KSM*22], climate modeling [BKV*20a], and astronombiology [BAE*18]. Often, an audience may be uninterested or apathetic to the science behind a

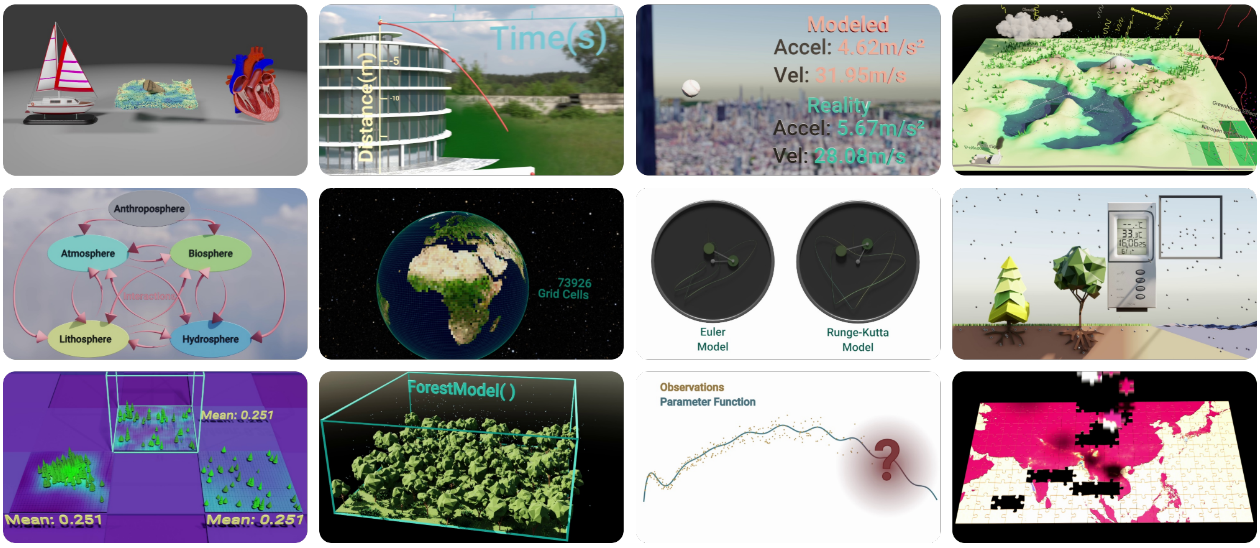


Figure 1: *Stills from the explainer video*

specific visualization and may have difficulty engaging intellectually with the content. Narrative visualization is a great method for engaging these individuals while weaving in complex information in a palatable format [BKV*20b]. There are conflicting findings on whether this truly benefits learning. One study found no difference for information recall with or without storytelling elements [ZLB22], while another observed that acquired insights/teaching effectiveness is significantly improved with storytelling elements [SME*24].

The role of interactivity in narrative visualization has received significant attention, with research finding that interactivity improves engagement with the medium and reduces confusion [ZOM19; Ale16; MGM*23]. There are also conflicting studies finding that interactive elements can distract from the non-interactive elements and reduce recall despite a perception of control and comprehension [PEDO20; XS16]. In a study regarding interactivity in scientific articles, researchers used eye tracking to observe participant engagement with and without interactivity. They found that recall correlates with time of fixation of the eyes. Time of fixation was higher on interactive components vs. non-interactive components. Thus, results suggest the interactive components aid in recall and memory [GKB20]. There has been no prior study comparing the effectiveness of interactive and illustrated articles vs. video formats. However, there have been studies demonstrating the benefits of interactivity in video formats. Specifically, sporadic quizzes during the viewing experience to ensure comprehension as well as a summary at the end. Students exposed to this format performed 28 % better than their counterparts who were not [KDK22].

3. Storyboard

The central narrative aims to address why, despite the advanced capabilities of modern computing, climate researchers struggle to accurately predict long-term climatic conditions. Furthermore, it explores how machine learning processes could be leveraged to enhance these predictions. This narrative builds a conceptual foundation on which more and more specific concepts are added. The details and facts of the narrative were co-developed/checked by an expert of 20+ years in the respective field. The overarching narrative is summarized as:

1. What are models?
2. When are models accurate?
3. What causes them to be inaccurate?
4. Improving a simple model with parameterization
5. Using models to describe the Earth System
6. The primary sources of error in those models
7. Using parameterization to address issues
8. Using machine learning to further improve parameterization
9. Outlook of machine learning and climate sciences

In the article format, this narrative is accompanied by images, animations, and interactive components. The video format is simply a continuously running animation that directly links visuals to a voiceover of the narrative.

4. Format Development

Two separate multi-modal formats of the same narrative were developed, one being an explainer video with two learning modalities (visual and audio) and an interactive article with three learning modalities (reading, visual, and kinesthetic). The narrative itself concerns the uncertainties in earth system models and their abilities to predict future climatic conditions.

Although both formats share the same overall narrative/script, they have slight dissimilarities to cater to either format's strengths. The video format rigidly follows the narrative, only varying when certain text could be easily shown visually. The article format follows the narrative exactly. However, potential jargon words have definitions attached to them, and some figures have more explanation within captions that would be seen in the video version of the figure. This extra text serves to provide additional context to counteract the lack of visual context seen in the video. There are an additional **18** definitions or explanations and **21** figures that include additional text not found in the original narrative. All in all, the article has roughly 1200 more words in the form of definitions and captions throughout the article compared to the number of spoken words in the video narrative.

4.1. Explainer Video

The explainer video follows a clear and straightforward "show-and-tell" format. A narration is accompanied by high-quality 3D animations that follow the spoken content (see Fig. 1). This serves to engage the dual coding benefit of multimodal learning and reduce cognitive load as there is no delay between the literal presentation of information and the accompanying visualization. The video format also tries to limit the amount of text on the screen to limit the splitting of attention in line with the redundancy principle [KS14]. Completely eliminating text elements was not feasible, as certain concepts required textual labels to identify specific components such as graphs, variables, methods, equations, and abstract ideas. The visuals were developed in an iterative process with individuals familiar with the concepts providing their input and ideas. All elements were modelled, animated, and rendered in Blender.

The final video has a duration of 12 minutes and 27 seconds.

4.2. Interactive Article

The interactive article utilizes text and images/animations to facilitate dual coding. Additionally, it introduces a third modality through interaction, which boosts engagement and offers a visual and kinesthetic dual-coding experience. This is intended to help readers process and integrate concepts previously covered in the text.

There are three main interactive elements in the article:

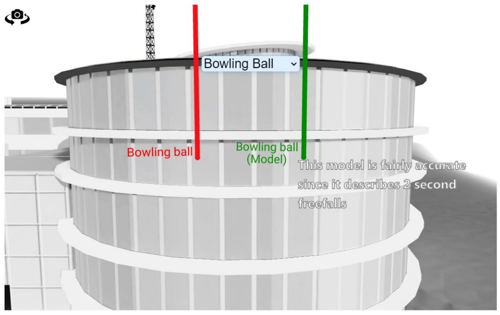
1. Toggleable figures of specific words/phrases
2. Toggleable definitions of specific words
3. Interactive apps of specific concepts

The toggleable elements include simple pop-ups that display when a mouse hovers over an element with an accompanying graphic/display or when tapped on a touchscreen device. Each graphic is a frame or visual inspired by the video format, accompanied by a description to provide a bit more context to the visual.

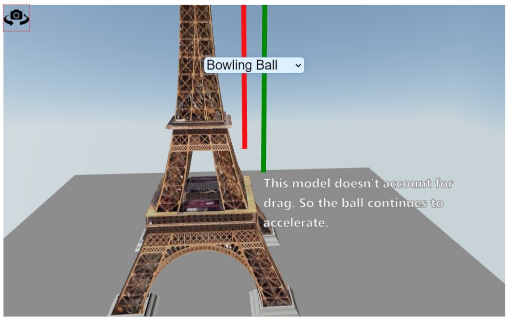
The interactive apps serve as a medium to engage the reader's attention and provide a pause from reading. It also introduces a more "tangible" example of the concepts being discussed in the narrative. There are four interactive apps embedded in the text of the interactive article - a link for which can be found in the supplement document.

Freefall

The first interactive app is a demonstration of an extremely naive model of freefall - a quadratic equation fit to the first two seconds of a more accurate model of freefall. Here, users see that when we



(a) *First free-fall scene*



(b) *Second free-fall scene*

Figure 2: *This application demonstrates how a model is only as accurate as the conditions for which it was developed (a). When using the same "model" in a new location, it stops being accurate (b).*

compare different types of balls and their models against "reality", it matches pretty well since the distance it falls only takes around two seconds (see Fig. 2a). The user can then swap the scene to drop balls from 300m. Now, the simple model fails to reflect "reality" since it does not account for wind resistance (see Fig. 2b). The goal of this application is to internalize that a model is only as good as the conditions where it was developed, therefore there are uncertainties to model predictions in climatic conditions that have not occurred.

Resolution

The second app is a simple interface that displays a satellite image of Europe and two buttons - one button causes the resolution of the image to increase and the other causes the resolution to decrease (Fig. 3). The narrative describes how information is "lost" when we use lower-resolution data. This provides a simple and clear example of the loss of information when using resolutions necessary for climate model predictions.

Double Pendulum.

This app is a comparison of two numerical methods for solving non-differentiable equations/systems (Fig. 4). The narrative mentions how some processes are complicated and difficult to describe in a model. Here, we want to demonstrate that although we can create equations to perfectly describe the physics of an understood

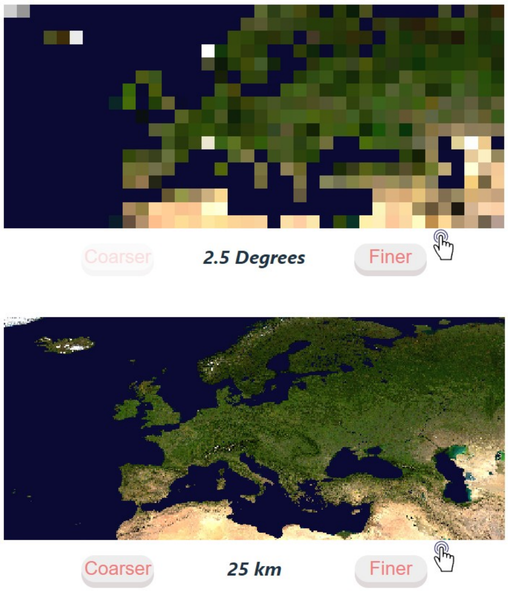


Figure 3: *This interface displays how spatial information is lost when land attributes are aggregated to more computationally manageable resolutions. (2.5°≈ 275km)*

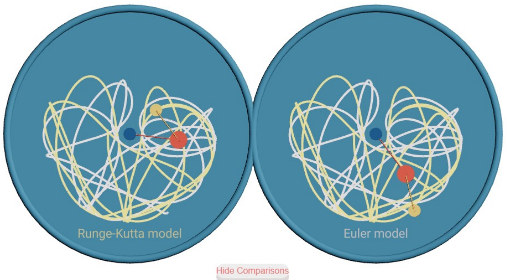


Figure 4: *This app demonstrates that even when we know exactly how to solve a system, the way in which we model it still plays a significant role in accuracy.*

process/system, if that equation cannot be solved analytically, then there are varying levels of accuracy we can achieve. This highlights the difficulty in modeling even more complicated or less understood processes and contributes to our uncertainty with future climate predictions made by models.

Fluid Sim.

The final app is a fluid simulation that compares two different resolutions for the same simulation. An aspect highlighted often in the narrative is the need to reduce the resolutions of predictions so that they are computationally manageable. With this app, we demonstrate that if we use the exact same model/method but change the resolution, we can see how the evolution of the process being modeled diverges. This is accomplished by stacking two simulations on top of each other (Fig. 5), moving your mouse or finger over one sends an identical signal to the other. One can see exactly how these

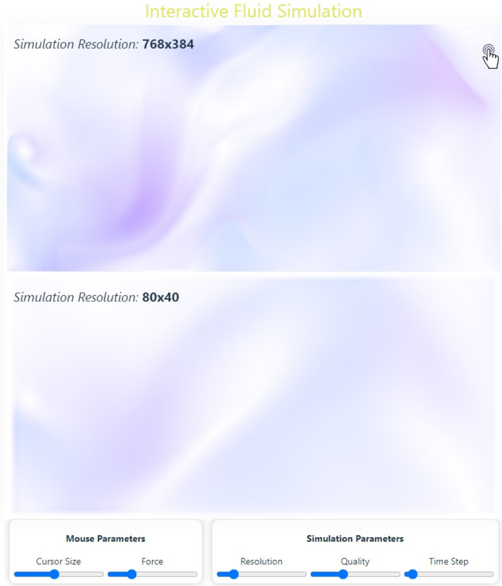


Figure 5: *This fluid simulation demonstrates how lower resolutions affect predictions over time. The above simulation is set at a constant resolution, with the bottom one providing user-defined coarser resolutions. The users can see how details and the evolution of the processes differ with lower resolutions.*

simulations diverge over time and the importance of resolution for accurately capturing the behavior of the fluids. The goal of this app is to demonstrate precisely what we lose by using lower-resolution data. Similar to the resolution app, this also demonstrates what is lost at the resolutions climate models use to predict atmospheric states.

5. User Study

This study implements a between-group design where participants are split into two groups. Each group learns from either a video or an interactive article. These users are then asked questions about the content discussed in the narrative to determine immediate recall of information. Users are then asked/prompted to return in a week to see how much information was retained. The goal is to determine whether one format provides lasting saliency of information over the other. We hypothesize that the instantaneous benefits of an explainer video and the accompanying visuals will provide a more resilient memory for the viewer.

5.1. Host Site

The primary purpose of the host site is to provide an easily accessible entry for participants into the study and control access to information. That is, we want to ensure people are answering questions solely based on relevant information with no potential for cross-contamination or simply opening a second instance of the narrative to "cheat" and get the correct answers. The site also allows us to track the simple behavior of users - time spent on a format and when/where they click.

5.2. Participants

The majority of participants were gathered via a post on YouTube, with additional participants from posts on other social media sites and connections with friends/colleagues. There were no demographic restrictions imposed. As the majority of participants were recruited from YouTube, there may be a slight performance bias for the video format.

The demographics of participants were recorded to identify potential biases and trends in the population. A geographical overview of participants can be seen in Figure 6, and a breakdown of key demographics can be found in Figure 7. The largest bias in demographic data is that of male vs non-male imbalance (88 % male). This may be a potential hindrance for generalizability. A meta-analysis found no broadly significant differences between genders with respect to performance with e-learning, however, the authors highlight two smaller studies that did observe significant differences between genders in two different countries [YD22]. Therefore, some nuance in this study may have been missed due to the male bias. This bias is an unfortunate trade-off for a larger sample size given the available resources.

5.3. Quiz

Information retention/recall was evaluated using a quiz of 20 questions: 13 multiple choice and 7 true/false. These questions focus on information retention of specific details in the narrative and not information transfer. This ensures that the interpretation of information doesn't affect performance. Ideally, the only difference will be whether the participant was engaged enough to notice and ingest the information that was presented. After one week the same questions are again presented to the viewer. In this second instance, questions received slight adjustments to their wording to lessen the likelihood of triggering episodic memory and a user selecting what they remember selecting. This increases the likelihood of users answering from semantic memory. An example of this rewording is:

> *What are the two primary ways researchers improve ESMs?*

becomes

> *What are the two main approaches researchers use to enhance ESMs?*

A full list of questions can be found in the supplement material.

6. Participant Data

Data is split into two datasets. The first comprises the responses from the initial viewing of the narrative and questionnaire. The second comprises responses after a one-week delay. In order to ensure anonymity, all demographic information is tied to the first dataset, as participation in the second dataset required an email address. However, if a participant used the same browser for the follow-up quiz, data stored on their browser was able to link this entry to their entry on the first quiz and demographic data. All datasets are available in the supplementary document.

6.1. Preprocessing

Each user entry has a unique ID and IP. IDs are browser-specific and can only be submitted once; duplicate IDs were discarded, while duplicate IPs were retained if demographic data differed, indicating shared network use.

To ensure data consistency, a "good faith" filter was applied. Many YouTube users have a video bias, therefore spending minimal time on the article and skewing quiz scores to random levels (6-7 correct answers). To address this, users spending less than half the median completion time on a format were excluded, as they likely didn't engage with the content in good faith. This is discussed further in Section 8.

6.2. Samples

There were **709** submissions for the first round of questioning. After applying the "good faith" filter. That number dropped to **622**. The majority of these losses were for those assigned the article format as seen in Table 1. 279 participants viewed the article format while 343 viewed the video format. After one week those dropped to 135 and 183 respectively

Table 1: *Sample count before and after "good faith" filtering for the initial follow-up quizzes. (%) is the percentage of original samples*

Format	**Samples Before**	**Samples After**
Article	351	279(79%)
Video	358	343(95%)
Follow-up	Samples	
Article	135(38%)	
Video	183(51%)	

7. Analysis

Two different formats of the same narrative were presented to a general audience to identify if one format provides greater information retention/recall than the other. This involves both immediately after as well as after a one week period. Additionally, various pre-survey questions and demographic information were used to assess whether initial preference influences recall and if there are any trends with regard to population. Finally, user behavior will be assessed to determine the efficiency and performance of each format with regard to information recall.

Trend analysis and significance are derived from linear least-squares regression.

7.1. Performance

Both formats displayed no statistically significant difference in performance for either the initial or delayed recall of information. This can be seen in Table 2.

To account for the imbalance in samples (Table 1), a distribution of 279 randomly selected samples from the video data were compared against the 279 of the article format. This t-test was repeated 1000 times with each iteration resampling from the video

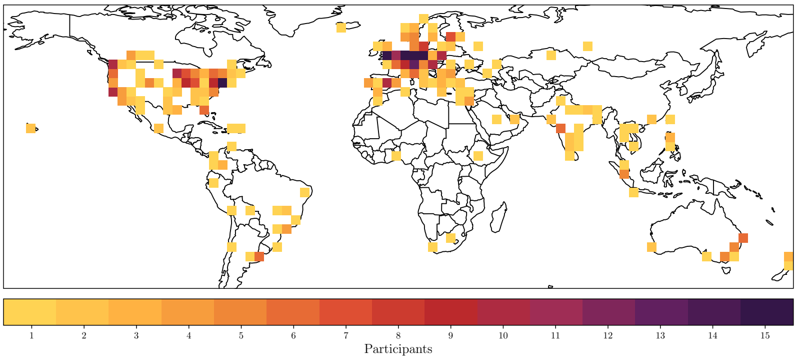


Figure 6: *A heat map of the participants in the study.*

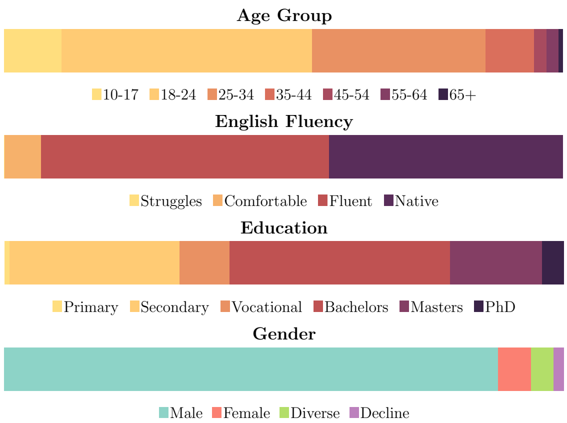


Figure 7: *Graphical/Percentage breakdown of demographic groups.*

Table 2: *The mean and median correct responses for samples given the initial and delayed recall quiz. Below are the t-statistics comparing the two distributions*

Metric	**Initial Recall**		**Delayed Recall**	
	Video	Article	Video	Article
Mean	15.12	14.90	14.90	14.73
Median	15	15	15	15
StDev	2.08	2.33	2.09	2.29
T-stat	1.22		0.66	
P-value	0.22		0.51	

samples. The average p-value for all 1000 iterations was **0.27** with only four iterations yielding a significant outcome. The same 1000 iterations were conducted for the delayed recall data. This yielded an average p-value of **0.55** with no iterations yielding a significant result. We conclude that, contrary to our hypothesis, the video format failed to outperform the article format for general audiences with statistical significance.

Table 3: *Article interactivity metrics. Click Interval→ seconds between two clicks | CPM → Clicks Per Minute*

	Per User		
	Clicks	Click Interval	CPM
Mean	89.9	15.6	5.22
Median	70	11.0	4.69
StDev	85.7	16.0	3.36

7.2. Engagement and Interactivity

The time participants spent on each format (engagement) was recorded along with the number and frequency of clicks for those viewing the article (interactivity). With this data, we can observe whether engagement or interactivity with a medium correlates to better performance.

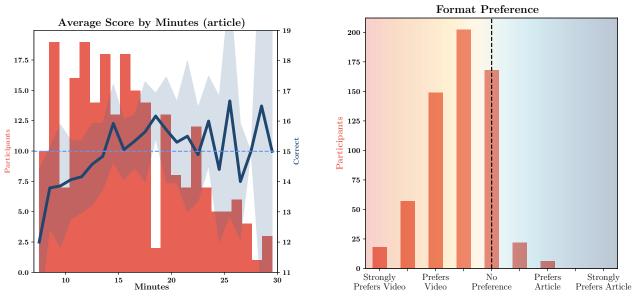
Engagement or time spent only correlated with quiz performance on the article format (Fig. 8a). This trend peaks at 18.5 minutes and then levels off with noise.

Interactivity is measured with three metrics: total number of clicks, clicks per minute, and click interval - the amount of time between clicks. For improved analysis, samples with less than 10 clicks are removed. No metric or combination of metrics yielded a statistically significant correlation to quiz performance. An overview of interactivity can be seen in Table 3 and further analysis along with graphs are found in the supplement.

7.3. Preference

Participants were asked to rank their likelihood of viewing scientific content in different formats on a scale from 1 (never) to 5 (always). Media preference is determined by subtracting one ranking from another, with negative values indicating a preference for videos and positive values for articles. This distribution is seen in Figure 8b.

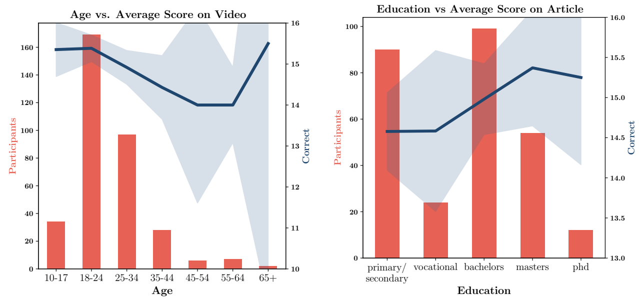
There was no significant trend between preference and performance on either format. In other words, someone's prior affinity for a specific format did not affect how they performed or retained information. There is, however, a noticeable trend on the article format, but it is not significant due to participants with a strong video



(a) *Minutes spent on article vs average performance.* $P = 0.0005$. *The dotted line represents the median score. (Graph capped at 30 minutes)*

(b) *User preference to scientific content.*

Figure 8: *(a) Engagement vs. correct answers for the article (b) Media preference of participants*



(a) *The average correct responses on after-quiz by age-group.* $P = 0.004$

(b) *The average correct responses on after-quiz by education.* $P = 0.038$

Figure 9: *Trend analysis of demographics and information recall. Only Age-Video and Education-Article combinations exhibited statistically significant trends.*

preference with strong after quiz performance. Excluding these potential outliers reveals a significant trend. This is seen in the supplement.

7.4. Demographic Trends

By examining performance across different demographics, we can spot statistically significant trends. We found that age has a negative correlation with performance in video formats, with the best results seen in individuals under 24. Performance decreases as age increases (see Fig. 9a). The lack of such a strong trend in the article format implies this effect isn't solely due to cognitive changes or the time elapsed since education. A more thorough study is necessary to confirm this effect.

A positive trend for education and average performance is found on the article format (see Fig. 9b). This does align with the views of Lin et al. [LZ23] that undergraduates must learn to extract and infer a deeper analytical understanding of a topic from text, and this is a skill set that develops with education. For transparency, the article data included three "primary" education samples with an average of 12 correct answers. Concerns arose that these values skewed the trend ($P = 0.027$ if left alone), so they were combined with the secondary education group. The effect remains significant. For all other demographics (age, education, occupation, English fluency), there exists no discernible trend in the data for performance on either format outside of those in Figure 9.

7.5. Efficiency

The measurable difference in information retention/recall between the two formats is marginal. However, the amount of time users spend on each format differs significantly. Although individuals usually read faster than a speaker, the interactive components significantly increase the variation of time spent depending on the degree of interaction. Users may spend more time either playing around with the interactive components or reading the additional text. This resulted in a greater mean and median amount of time spent on the article vs. the video. If we consider the time spent vs. information retained as a type of "teaching efficiency." Then we can see that the video format provides **29 %** greater teaching efficiency than the article format as seen in Table 4. For each minute spent learning, more information is retained from the video format than from the article format.

Table 4: *Time to complete each format along with efficiency scores*

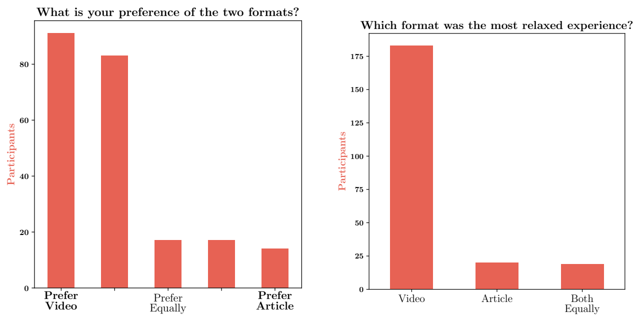
Time(m)	Video	Article
Mean	13.12	21.21
Median	12.69	16.44
StDev	6.09	16.9
Median Efficiency (Correct Answer/Minute)	1.18	0.91

7.6. After Survey

After the second quiz, a week later, or immediately if the participant chose not to return, users could view the format they hadn't seen. They were then prompted to fill out a survey providing their impressions. The primary purpose was to gauge qualitative opinions of both formats and if there was any change in preference or perceptions after exposure to both. Due to permission issues on local scripts, there was a period where requests to save survey results were heavily limited. This likely resulted in less than half of the survey responses being saved. Since the survey was not required it's uncertain what percentage is missing.

As the majority of participants were recruited from YouTube, it is no surprise that the majority of participants found the video format to be preferable (see Fig. 10). A comment seen multiple times was the difficulty of concentrating on the article due to ADHD and a wandering mind. There were also multiple responses from those with and without ADHD, preferring the video as they could watch it at faster speeds.

With regard to the article, multiple users expressed that it took more time to complete compared to the video. Additionally, although aims were taken to try to break up text to prevent large text sections that may overwhelm readers. On mobile devices, there are a few sections where no images are visible on the screen. There are, however, always interactive components visible regardless of screen resolution. Multiple users also mention moments of boredom or disconnect during larger portions of text, which may be related to these sections. Another potential issue mentioned was that apps required a slight learning period to understand. The time to understand and interact with the apps caused a disruption in the flow of reading through the article. This connects to previously discussed findings that interactivity can distract [PEDO20; XS16]. A few responses postulated the benefits of a combination of the two formats. The cohesion of the video format with the interactive components of the article. This potential could link to the benefits seen in work discussed earlier [KDK22]. All survey responses can be found in the supplement.



(a) *User Preference of both formats* **(b)** *User response to ease of learning experience*

Figure 10: *Two after-survey questions querying participant experience*

8. Discussion

Both video and interactive article formats showed no significant difference in information retention, whether immediately or after a week. This suggests that both formats are equally effective for general audiences. They do, however, differ in engagement with the median article reader spending **29 %** more time absorbing the information compared to video viewers. This, combined with similar test results, makes video a more efficient format for disseminating climate science vs an interactive article.

Creating an engaging video requires an upfront investment of time to capture viewers' attention and effectively convey knowledge. Developers must consider whether the time and efficiency saved by the audience justifies this investment. A utilitarian approach for efficiency would recommend creating articles for smaller audiences and videos for larger audiences.

The "good faith" filter is likely to instill some skepticism. However, we believe the results support this decision. Keeping all of the samples would have demonstrated a clear and definitive advantage for the video format, as participants who sped through the article also had markedly low scores on the quiz. Additionally, since the video can not be watched faster than 2x speed, someone who finished the video faster than the good faith check would have had to skip some sections. Individuals returning after a week to retake the quiz are thought to have engaged in the material with good faith. For these individuals, we see no difference in information retention between the two formats. For these reasons, we believe the good faith filter is an appropriate measure.

The large sample count comes with a very notable male bias. Although a meta-analysis finds no strong differences between male and female e-learners. The very same meta-analysis identified two studies that did find notable differences between male and female populations. It is possible some nuance is lost with such a biased demographic and the findings can not be widely applicable. However, given the strength of the effects it's unlikely the teaching efficiency and negative trend with age on the video change with better female representation. It is possible that the positive trend with education on the article would change as this trend is only marginally significant ($P = 0.038$). A replication study or an increase in female samples using this same study would be beneficial in legitimizing the generalizability of these results.

Although the metrics used to assess interactivity show no correlation or benefit from interaction. These metrics are themselves a bit limited and lack nuance. It's possible, by monitoring interaction at an element/component level, we may find that interacting with types of components (Apps, Definitions, Graphics) correlates to performance. Eye-tracking is also a useful tool to assess the level of engagement but is missing from this study. Nevertheless, the complete lack of correlation within available metrics raises some questions about the efficacy of interaction. Although interaction does increase engagement and time spent with the information. If this effort does not correlate to more retention, then the purpose of its inclusion in this format is a bit unclear.

9. Conclusion and Future Work

In this study, we compared the effectiveness of two multimodal learning approaches—an explainer video and an interactive article—in conveying complex climate science concepts, particularly the uncertainties in climate models. Our findings indicate that both formats are equally effective in terms of information retention, with no significant difference observed between immediate and delayed recall. There exists a statistically significant negative trend for performance and age with the video format and a positive trend for education and information retention on the article format. Additionally, the three metrics available to quantify interactivity with the article all demonstrated no correlation with information retention/recall.

Despite equivalent performance for recall, the video format demonstrated higher teaching efficiency. The article format required ~**30 %** more time for the median user to absorb the same amount of information compared to the video format.

The choice between producing a video or interactive article should consider the intended audience size and the resources available for content creation. For smaller audiences, the lower production cost of articles may be more practical, while videos are more suitable for larger audiences due to their efficiency.

This study builds on previous studies that compared the performance of video and text readers by adding an additional component of interaction to the article. Although metrics that represent interaction show no correlation to retention, there was no control group to further isolate this effect. A replication of this study using the same set-up, minus the interactivity, or simply two articles with/without interactivity would be beneficial in isolating positive or negative effects. One might also consider tracking interactions for each individual component rather than the article as a whole. This would further identify which elements promote engagement and those that are potentially unnecessary. Additionally, the style of the video and layout of the article may also have an impact. Perhaps a visually simple video of the same narrative or a different design of the article would elicit changes in retention. Future work may consider employing multiple developers to construct multiple versions to provide unique and different experiences. Lastly, a replication with balanced demographic representation would be beneficial in clearing up potential uncertainties with regards to potential male vs female nuance as well as confirming whether the strength of the teaching efficiency observed in this study holds up.

10. Acknowledgments

Open Access funding enabled and organized by Projekt DEAL.
This research is part of the AI4PEX (Artificial Intelligence and Machine Learning for Enhanced Representation of Processes and Extremes in Earth System Models) project and has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement no. 101137682.
Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union, the European Climate, Infrastructure and Environment Executive Agency (CINEA), UKRI or SERI. Neither granting authority can be held responsible for them.

References

[Ale16] ALEXANDRE, ILO. "Promoting Insight: A Case Study of How to Incorporate Interaction in Existing Data Visualizations". *Proc. of International Conference Information Visualisation (IV)*. Lisbon, Portugal: IEEE, 2016, 203–208. ISBN: 978-1-4673-8942-6. DOI: 10.1109/IV.2016.15.

[BAE*18] BOCK, ALEXANDER, AXELSSON, EMIL, EMMART, CARTER, et al. "Openspace: Changing the narrative of public dissemination in astronomical visualization from what to how". 38.3 (2018), 44–57.

[BKV*20a] BÖTTINGER, MICHAEL, KOSTIS, HELEN-NICOLE, VELEZ-ROJAS, MARIA, et al. "Reflections on Visualization for Broad Audiences". *Foundations of Data Visualization*. Springer, 2020, 297–305.

[BKV*20b] BÖTTINGER, MICHAEL, KOSTIS, HELEN-NICOLE, VELEZ-ROJAS, MARIA, et al. "Reflections on visualization for broad audiences". *Foundations of data visualization* (2020), 297–305.

[CD18] CUEVAS, JOSHUA A. and DAWSON, B. L. "A test of two alternative cognitive processing models: Learning styles and dual coding". *Theory and Research in Education* 16 (2018), 40–64. DOI: 10.1177/1477878517731450.

[CP91] CLARK, JAMES M. and PAIVIO, ALLAN. "Dual coding theory and education". *Educational Psychology Review* 3 (1991), 149–210. URL: https://api.semanticscholar.org/CorpusID:17872676.

[CSW99] CHAPMAN, P., SELVARAJAH, S., and WEBSTER, J. "Engagement in multimedia training systems". *Proc. of the Hawaii International Conference on Systems Sciences*. IEEE Comput. Soc, 1999, 9. ISBN: 978-0-7695-0001-0. DOI: 10.1109/HICSS.1999.772808.

[DK22] DRUZHBA, OLGA and KHAN, ROKSANA. "The perception of various media formats of educational content by the youth audience". *E3S Web of Conferences* 363 (2022). Ed. by MALYGINA, I., 03026. ISSN: 2267-1242. DOI: 10.1051/e3sconf/202236303026.

[GKB20] GREUSSING, ESTHER, KESSLER, SABRINA HEIKE, and BOOMGAARDEN, HAJO G. "Learning From Science News via Interactive and Animated Data Visualizations: An Investigation Combining Eye Tracking, Online Survey, and Cued Retrospective Reporting". en. *Science Communication* 42.6 (2020), 803–828. ISSN: 1075-5470, 1552-8545. DOI: 10.1177/1075547020962100.

[HJL23] HAAVISTO, MIKKO, JAAKKOLA, TOMI, and LEPOLA, JANNE. "Video outperforms illustrated text: Do old explanations for the modality effect apply in a learner-paced fifth-grade classroom context?": *Computers & Education* 199 (2023), 104775. ISSN: 03601315. DOI: 10.1016/j.compedu.2023.104775.

[KDK22] KIT'S COLLEGE OF ENGINEERING (AUTONOMOUS), KOLHAPUR 416234, MAHARASHTRA, INDIA, DESAI, T. S., and KULKARNI, D.C. "Assessment of Interactive Video to Enhance Learning Experience: A Case Study". *Journal of Engineering Education Transformations* 35.S1 (2022), 74–80. ISSN: 23492473, 23941707. DOI: 10.16920/jeet/2022/v35is1/22011.

[KHS22] KULGEMEYER, CHRISTOPH, HÖRNLEIN, MADELEINE, and STERZING, FABIAN. "Exploring the effects of physics explainer videos and written explanations on declarative knowledge and the illusion of understanding". *International Journal of Science Education* 44.11 (2022), 1855–1875. ISSN: 0950-0693, 1464-5289. DOI: 10.1080/09500693.2022.2100507.

[KS14] KALYUGA, SLAVA and SWELLER, JOHN. "The Redundancy Principle in Multimedia Learning". *The Cambridge Handbook of Multimedia Learning*. Ed. by MAYER, RICHARD E. 2nd ed. Cambridge University Press, 2014, 247–262. ISBN: 978-1-139-54736-9 978-1-107-61031-6 978-1-107-03520-1. DOI: 10.1017/CBO9781139547369.013.

[KSM*22] KLEINAU, ANNA, STUPAK, EVGENIA, MÖRTH, ERIC, et al. "Is there a tornado in alex's blood flow? A case study for narrative medical visualization". *Proc. of Eurographics Workshop on Visual Computing for Biology and Medicine*. Eurographics. 2022.

[LB19] List, Alexandra and Ballenger, Eric E. "Comprehension across mediums: the case of text and video". *Journal of Computing in Higher Education* 31.3 (2019), 514–535. issn: 1042-1726, 1867-1233. doi: 10.1007/s12528-018-09204-9.

[LLC*21] Lackmann, Sergej, Léger, Pierre-Majorique, Charland, Patrick, et al. "The Influence of Video Format on Engagement and Performance in Online Learning". *Brain Sciences* 11.2 (2021), 128. issn: 2076-3425. doi: 10.3390/brainsci11020128.

[LZ23] Lin Yu-peng and Zhonggen Yu. "A Meta-analysis Evaluating the Effectiveness of Instructional Video Technologies". *Technology, Knowledge and Learning* (2023), 1–35. doi: 10.1007/s10758-023-09669-3.

[MGM*23] Mittenentzwei, Sarah, Garrison, Laura A, Mörth, Eric, et al. "Investigating user behavior in slideshows and scrollytelling as narrative genres in medical visualization". *Computers & Graphics* 114 (2023), 229–238.

[MGS*22] Meuschke, Monique, Garrison, Laura A, Smit, Noeska N, et al. "Narrative medical visualization to communicate disease data". *Computers & Graphics* 107 (2022), 144–157.

[MHMC05] Mayer, Richard E, Hegarty, Mary, Mayer, Sarah, and Campbell, Julie. "When static media promote active learning: annotated illustrations versus narrated animations in multimedia instruction." *Journal of Experimental Psychology: Applied* 11.4 (2005), 256. doi: 10.1037/1076-898X.11.4.256.

[MVHS15] Meppelink, Corine S, Van Weert, Julia Cm, Haven, Carola J, and Smit, Edith G. "The Effectiveness of Health Animations in Audiences With Different Health Literacy Levels: An Experimental Study". *Journal of Medical Internet Research* 17.1 (2015), e11. issn: 1438-8871. doi: 10.2196/jmir.3979.

[NGD*21] Noetel, Michael, Griffith, Shantell, Delaney, Oscar, et al. "Video Improves Learning in Higher Education: A Systematic Review". *Review of Educational Research* 91.2 (2021), 204–236. issn: 0034-6543, 1935-1046. doi: 10.3102/0034654321990713.

[PBM*19] Pujol, Jesus, Blanco-Hinojo, Laura, Martínez-Vilavella, Gerard, et al. "Brain activity during traditional textbook and audiovisual-3D learning". *Brain and Behavior* 9.10 (2019), e01427. issn: 2162-3279, 2162-3279. doi: 10.1002/brb3.1427.

[PEDO20] Pajor, Emília Margit, Eggers, Sander Matthijs, De Vries, Hein, and Oenema, Anke. "Effects of Interactivity on Recall of Health Information: Experimental Study". *Journal of Medical Internet Research* 22.10 (2020), e14783. issn: 1438-8871. doi: 10.2196/14783.

[Sch20] Schneiders, Pascal. "What Remains in Mind? Effectiveness and Efficiency of Explainers at Conveying Information". *Media and Communication* 8.1 (2020), 218–231. doi: 10.17645/mac.v8i1.2507.

[SME*24] Shao, Hongbo, Martinez-Maldonado, Roberto, Echeverria, Vanessa, et al. "Data Storytelling in Data Visualisation: Does it Enhance the Efficiency and Effectiveness of Information Retrieval and Insights Comprehension?": *Proc. of the CHI Conference on Human Factors in Computing Systems*. ACM, 2024, 1–21. isbn: 9798400703300. doi: 10.1145/3613904.3643022.

[VSV14] Van Den Broek, G.S.E., Segers, E., and Verhoeven, L. "Effects of text modality in multimedia presentations on written and oral performance". *Journal of Computer Assisted Learning* 30.5 (2014), 438–449. issn: 0266-4909, 1365-2729. doi: 10.1111/jcal.12058.

[XS16] Xu, Qian and Sundar, S. Shyam. "Interactivity and memory: Information processing of interactive versus non-interactive content". *Computers in Human Behavior* 63 (2016), 620–629. issn: 07475632. doi: 10.1016/j.chb.2016.05.046.

[YD22] Yu, Zhonggen and Deng, Xinjie. "A Meta-Analysis of Gender Differences in e-Learners' Self-Efficacy, Satisfaction, Motivation, Attitude, and Performance Across the World". *Frontiers in Psychology* 13 (May 2022), 897327. issn: 1664-1078. doi: 10.3389/fpsyg.2022.897327. url: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.897327/full (visited on 02/19/2025).

[YPL*11] Yadav, Aman, Phillips, Michael M., Lundeberg, Mary A., et al. "If a picture is worth a thousand words is video worth a million? Differences in affective and cognitive processing of video and text cases". *Journal of Computing in Higher Education* 23.1 (2011), 15–37. issn: 1042-1726, 1867-1233. doi: 10.1007/s12528-011-9042-y.

[ZLB22] Zdanovic, Dominyk, Lembcke, Tanja Julie, and Bogers, Toine. "The Influence of Data Storytelling on the Ability to Recall Information". *Proc. of ACM SIGIR Conference on Human Information Interaction and Retrieval*. ACM, 2022, 67–77. isbn: 978-1-4503-9186-3. doi: 10.1145/3498366.3505755.

[ZOM19] Zhi, Qiyu, Ottley, Alvitta, and Metoyer, Ronald. "Linking and Layout: Exploring the Integration of Text and Visualization in Storytelling". *Computer Graphics Forum* 38.3 (2019), 675–685. issn: 0167-7055, 1467-8659. doi: 10.1111/cgf.13719.