Crafting Memorable Science Stories: Harnessing the Power of Narrative Peaks in Online Science Videos

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Online platforms have transformed science communication by making complex concepts more accessible and engaging. However, the rise of infotainment risks diluting the depth and accuracy of knowledge transmission. In response, our study investigates the integration of narrative peaks, key moments of the most impressive part within narrative structures, aiming to enhance the memorability of online science video(OSV) narrative making. By combining theoretical insights with empirical data, including literature reviews and participant-driven annotations, we developed a design space to guide content creators in producing captivating yet accurate scripts. Preliminary quantitative experiments assessed the impact of various peak strategies on viewers' learning outcomes. The results suggest that different peak strategies affect knowledge retention distinctively, with structure-level strategies particularly promoting long-term learning effects. Further workshops with experienced content creators highlight how our design space supports the development of engaging yet informative OSVs, offering clear guidance for the effective development of narratives for OSVs.

CCS Concepts: • **Human-centered computing → Empirical studies in HCI**.

Additional Key Words and Phrases: Narrative Design, Learning Effect, Science Commnuication, Online Science Video

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1 INTRODUCTION

As digital platforms such as YouTube, Reddit, Github, and Tiktok continue to rise in popularity, they have replaced traditional media as the dominant source of information sharing for hundreds of millions of people globally, dramatically transforming science communication [17, 48, 50, 112, 132].

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Online Science Videos (OSVs) have emerged as a particularly effective medium for disseminating scientific knowledge, democratizing access, and enabling everyday users to actively engage in the exchange of knowledge [17, 61, 131, 132].

At the core of these OSVs are well-crafted narratives that leverage storytelling techniques to present, clarify, and explore diverse fields of knowledge in an engaging and accessible manner [41, 132, 135]. Effective narrative writing is crucial in ensuring that scientific concepts are communicated clearly and memorable to the viewer [47, 66].

To improve the effectiveness of narrative writing in OSVs, content creators frequently utilize established storytelling elements. Among these, narrative peaks, or climaxes, stand out as a crucial component, often representing the most impactful and memorable moments in storytelling [31, 35]. These dramatic moments show particular promise for enhancing science communication. By strategically incorporating narrative peaks into OSVs, content creators may be able to heighten audience engagement and improve knowledge retention.

Previous studies in science communication have predominantly concentrated on broader narrative approaches, employing methods like video coding, content analysis [94], literature reviews [49], and case studies [43] to explore their influence on popularity and audience engagement. However, they have paid less attention to specific narrative strategies, particularly at the structural or more granular level, and how these strategies affect audience learning outcomes.Similarly, while research on narrative structures and narrative peaks in media such as films and data videos has been conducted [4, 134], in HCI, little has been done to examine how narrative peaks can be systematically incorporated into OSV narratives to enhance knowledge retention.

Despite the growing importance of OSVs, there remains a significant gap in our understanding of how specific narrative strategies influence the audience's learning process and outcomes. To our knowledge, no previous investigation has combined theoretical knowledge from the literature, real-world example analysis, and empirical evaluation of these strategies' effects on key aspects such as memory retention, enjoyment, and cognitive load. Furthermore, there is a lack of research on how content creators can effectively implement these strategies in practice. This research aims to bridge that gap.

We raise the following research questions:

RQ1: *What narrative peak strategies for online knowledge communication learning content are identified in existing literature?*

RQ2: *What additional narrative peak strategies can be observed in real-world examples of online science videos?*

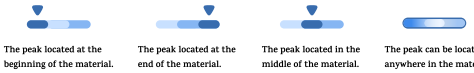
RQ3: *How can these strategies from literature and real-world examples be unified and categorized to create a comprehensive design space for narrative peaks for science communication?*

RQ4: *How do different types of peak strategies in narrative content impact viewers' memory retention, enjoyment levels, and perceived cognitive load, compared to content without peak strategies?*

RQ5: *How do content creators perceive and experience the ease of implementation of various peak strategies in online science communication content?*

To address **RQ1**, we conducted a literature review, identifying 11 peak narrative strategies. For **RQ2**, we employed an annotation process [76, 77], engaging four annotators to identify peaks in our corpus of OSVs. This analysis revealed 8 additional strategies not found in the literature. In response to **RQ3**, we synthesized these 19 strategies from literature and video analysis, systematically defining and categorizing them into 6 dimensions to construct an initial design space for OSV narratives.

To answer **RQ4**, we conducted a quantitative experiment with 16 participants to test the effectiveness of OSV content with and without peak strategies from our identified dimensions. The results showed varying effects. Applying structural-level strategies from *Enhance Introductions and Conclusions* and *Make Strategic Content Transitions* dimensions significantly improved 7-day



Level	Dimension	Peak Strategy	Position	Examples	Implementation Difficulty	Note
Word and Sentence level	Precision Language Optimization	(1) Use metaphors		To treat this disease, we'd need ..... and that's technology that scientists haven't figured out yet. But don't freak out, Creutzfeldt-Jacobs disease is extremely rare. **It's just as common as being struck by lightning.** - *The Disease You Will Never Survive*	Moderate	Need careful use and **word choice**
		(2) Use humor		So why do humans have noses that stick out, but other apes don't? **Now, nobody nose for sure, sorry,** but there are few good hypotheses as to why our snouts got so big. - *Why Do Our Noses Stick Out?*	Moderate to Hard	
		(3) Use multiple transition signal words together		**But** Sexual Differentiation in a brain, **actually** happens much later than Gonadal Differentiation. **And yes, although** controversial Male and Female brains have structural and functional differences between each other. - *The Science of Being Transgender*	Easy	
		(4) Use repetition of key terms		**Why do we yawn and why is yawning contagious? How come when I see someone yawn or even think about it it makes me kinda of want to yawn?** First things first, definitions. When you yawn, you inhale air and stretch your ear drums. - *Why Is Yawning Contagious?*	Easy	
Sentence level	Raise a Question	(5) Raise a question with an answer*		**So, what good does having a tiny fragment of viral spike in your body do? It gives your body, and more importantly your immune system .... Suddenly, your antibodies will notice it and go.** - *What the COVID vaccine does to your body?*	Easy	Improve **enjoyment** and decrease **cognitive load**
		(6) Raise a question without an answer		Robert Rosenthal concluded: "When we expect certain behaviors of others we are likely to act in ways that make the expected behavior more likely to occur.' **What do you think about this theory?** - *The Pygmalion Effect*	Easy	
Sentence and paragraph level	Add Narrative Elements	(7) Add stories or real-world examples*		The psychiatrist goes on to explain that ADHD symptoms can be treated with medication and therapy. ..... **When Lisa takes her first pill the next day, she bursts into tears. ..... She realizes that, throughout her whole life, she has spent so much energy trying to do things that others do without even thinking.** - *ADHD from Childhood to Adulthood*	Moderate to Hard, need Information	Need careful use and refine, and **avoid irrelevant content.**
		(8) Add an imagery description		In fact, why does the universe have any structure at all? **Imagine a different universe from our own, where all the matter is spread out, perfectly smooth and uniform. ..... then everything would be pulled to the center and would end up clumped in one place.** - *Why is The Universe So Empty?*	Moderate to Hard, need Information	
Structural Level	Enhance Introductions and Conclusions	(9) Open with the central theme or definition*		**Your brain is two brains. Two hemispheres each doing half the work of being you.** Half your vision goes to each and half your movement directed by each. - *You Are Two*	Easy	Enhance **memory**
		(10) Summarize the key knowledge at the end		Despite everything we know about the human body, **there are still some strange and enduring mysteries, like the placebo effect.** - *The Power of The Placebo Effect*	Easy	
Structural Level	Make Strategic Content Transitions	(11) Switch between pros and cons		With this new drive, DQN not only managed to grab that first key: it explored all the way through 15 of the temple's 24 chambers. **But emphasizing novelty-based rewards can sometimes create more problems than it solves. A novelty-seeking system that's played a game too long will eventually lose motivation.** - *How to Get Better at Video Games, According to Babies*	Moderate, need suitable context	Enhance knowledge **memory**, improve **enjoyment** and decrease **cognitive load**
		(12) Bridge expository and narrative elements		Economists call this a bubble. So what is exactly is going on with a bubble? **Well, let's start with the tulips to get a better idea.** - *What Causes Economic Bubbles?*	Moderate, need suitable context	
		(13) Shift between two knowledge points		**So, maybe life is information that manages to ensure its continued existence. But what about AI?** By our most common definitions, we are very close to creating artificial life in computers. It's just a question of time before the technology we build gets there. - *What is Life? Is Death Real?*	Easy to Moderate	
Any Level	Evoke Emotional and Affective Engagement	(14) Create quantitative emphasis		That's **nearly seven times** the amount that was burned during the Amazon rainforest fires of 2019. Or, put another way, it's **about twice the size of Belgium.** And this is what has led ecologists to estimate that **around 500 million animals** have already died in the fires, **including 8,000 koalas.** - *How Do Wildfires Affect Animals ?*	Moderate, need suitable context	Suitable for **specific content**, avoid emotional arousal levels that are either too low or too high.
		(15) Create negative emphasis for focused attention		The campaign worked and pushed the Chinese sparrow population to near extinction. So what about the unintended consequences? ..... **The consequence was the Great Chinese Famine, one of the largest man-made disasters in human history, with a death toll in the tens of millions.** - *Chesterton Fence: Don't Destroy What You Don't Understand!*	Hard, need suitable context and story	
		(16) Make positive emotion to expand action repertoire		It's not very much. And using a computer doesn't raise it that much higher, **but don't be discouraged, because typing and texting can bind us together.** ..... In fact, every day, 6 billion text messages are sent. And there are only 7 billion people on Earth. - *You Don't Type Alone*	Easy	

Fig. 1. **Final Design Space** of peak strategies including dimensions, final 16 strategies merged from the previous 19 strategies proposed through literature review and annotation indicated by the results in study 2, positions, corresponding examples, their implementation difficulty, and application suggestions.

* 1. Raise a Question with an Immediate Answer: Merged from "Raise a question with an immediate answer" and "Inquire and reveal."
* 2. Add Stories or Real-World Examples: Merged from "Add stories" and "Add real-world examples."
* 3. Open with the Central Theme or Definition: Merged from "Open with the central theme" and "Define key terminology at the beginning."

delayed free recall. Applying strategies from the *Raise a Question* dimension significantly enhanced reading enjoyment and marginally reduced cognitive load.

To our surprise, applying strategies from *Precision Language Optimization*, *Add Narrative Elements*, and *Evoke Emotional and Affective Engagement* dimensions did not significantly improve memory retention, enjoyment, or cognitive load. Post-study interviews revealed nuanced insights into this finding. Participant feedback suggested that these strategies' effectiveness depends largely on

personal preferences and experiences. Without strong personal connections to the content, added elements may have limited impact.

To further test and refine our design space and answer **RQ5**, we invited eight experienced content creators from related fields to use it for editing OSV narratives in a workshop study. Their feedback corroborated our experimental findings. They reported that many strategies from the three dimensions that showed no significant benefits in our earlier evaluation were more challenging to apply, making it difficult to achieve consistent results across audiences. In contrast, strategies from the three dimensions that demonstrated significant benefits were found to be much easier to implement, making them ideal candidates for more universal use.

In addition, our workshop participants found three pairs of strategies difficult to distinguish in practice. Consequently, we merged these pairs, refining our design space into a consolidated table **(Figure 1)** with 16 distinct strategies across 6 dimensions.

The contributions of our paper are threefold:

- We present a comprehensive design space for narrative peaks in OSV narratives, developed through systematic literature review and content analysis. This conceptual contribution provides a structured framework for understanding and exploring peak strategies in science communication.
- We empirically evaluate the strategies in the design space, providing evidence-based insights on their varying effectiveness in improving memory retention, enjoyment, and cognitive load. This evaluation reveals that while not all strategies show significant benefits, some can be particularly effective, offering valuable guidance for selective implementation.
- We validate and refine this design space through a workshop with experienced content creators, offering additional insights on the practical challenges of applying these strategies and incorporating the findings into the design space to form a more comprehensive guide for future narrative writing with peak strategies.

Together, these contributions offer nuanced insights into the use of narrative peaks in OSVs. This work aims to contribute to a more holistic understanding of how narrative peaks might be strategically leveraged to enhance impact in online science communication while also acknowledging both their potential benefits and limitations.

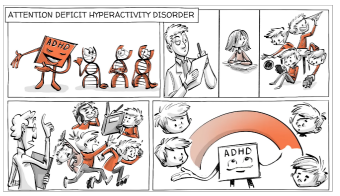
2 BACKGROUND AND RELATED WORK

2.1 Online Science Videos

Science communication has focused on making complex scientific concepts understandable, memorable, and enjoyable [95]. Traditionally, science communication is often limited to academic settings and specialized publications, with domain experts like scientists or journalists leading the discourse [51, 132, 135]. However, in the digital age, where knowledge is just a click away, platforms like YouTube [48], TikTok [97], and Bilibili [135] etc. have revolutionized science communication [17]. These platforms have democratized access, allowing ordinary people to actively engage in disseminating knowledge [17, 61, 131, 132] and fostering vibrant online communities that contribute back to scientific research, thereby enhancing its reach and impact [50]. Online Science Videos (OSVs), also known as online science media [114], science web videos [35], or science and knowledge communication videos [132], have become a popular medium for disseminating knowledge, providing the public with valuable opportunities for informal learning [97]. We especially focus on online science videos dedicated to knowledge dissemination, ensuring that complex concepts are described, explained, and discussed in a highly engaging and accessible manner [66, 132]. These videos include both Professionally Generated Content (PGC) from corporate entities and User-Generated Content (UGC) from non-academics [114, 132].

How the World Cup's AI instant replay works
(1.1m views) by ***Vox*** (12.3m subscribers)

Why Is The Universe So Empty?
(419k views) by ***Be Smart*** (5.24m subscribers)



ADHD from Childhood to Adulthood
(169k views) by ***Sprouts*** (1.71m subscribers)

Fig. 2. Widely viewed OSVs present knowledge in a highly engaging way, reaching and impacting millions of viewers across three different styles and themes. (Data accessed in 09/2024)

The narratives of OSVs often adopt an "infotainment" approach, where information is delivered in an engaging, often entertaining way [41, 49]. This style has proven effective in capturing audiences' attention and enhancing recall [1, 57, 114]. However, the primary goal of a science communicator is to convey scientific information accurately, enabling people to update and, when necessary, revise their understanding of the world [39]. While entertainment content can enhance engagement and boost the popularity of videos, research indicates that an overemphasis on entertainment can hinder meaningful learning, which requires cognitive effort [100, 105, 132], and diminish the educational value [132]. This emphasizes the need for systematic guidance on how to design better narratives of OSVs to ensure that science communication is not only engaging but also promotes a deep understanding of scientific concepts. This is especially crucial given that videos from UGC creators, who may lack formal training in science communication, are often more popular than those from PGC [131].

HCI research has significantly contributed to science communication through various digital mediums like Reddit [8, 69] and Twitter [56, 84], with a focus on making science accessible, engaging, and impactful. However, video-based science communication remains underexplored in HCI and CSCW. Only a few HCI studies have examined OSVs, such as one investigating communication strategies in science videos on Bilibili and their correlation with viewers' behavioral, emotional, and cognitive engagement [135]. Another study explored the motivations and practices of creators and the challenges they face [132]. There is still a lack of systematic research in HCI on the narrative strategies in OSVs to create engaging and effective science communication.

2.2 Narrative Structure and Narrative Peak

Narrative Structure, also known as Story Structure or Dramatic Structure, refers to the organized framework or sequence of events that shape a story, typically consisting of exposition, rising action, climax, falling action, and resolution [23, 27, 54, 89]. Stories are one of the most effective ways to make ideas meaningful and serve as a primary mode of communication and learning for thousands of years [11, 59], as they place new information within a familiar context, capturing attention and evoking emotion [**?**]. The narrative structure is crucial in making stories memorable, engaging, and impactful [11, 22, 85]. The structured format helps people organize and recall information [85, 127], encouraging deeper emotional and cognitive engagement [37, 59].

Narrative structure theories have been applied across various fields, including linguistics, graphics, and comics. Graphics studies often focus on integrating narrative theories with visualizations, like motion graphics [10, 136] and narrative visual sequences [67]. Cohn and others explored different narrative structures in comics [30, 33, 96, 106], examining the connection between visual layouts and narratives [5, 34]. In HCI, narrative structures are used in game studies [28, 117],

media arts [63], interaction design [14, 25], and AR [121, 122] to enhance immersion and comprehension. There are also many works on narrative strategies in data videos, such as influencing storytelling effectiveness [4, 75], emotional feelings [74, 81], and integrating visual narratives with animation [24, 119] and interactions [62].

Narrative Peak, also known as Narrative Climax, was first introduced by Freytag in 1895 as part of Freytag's Pyramid [54]. He defined it as the climax of the narrative structure, or "the crowning point of a great, amplified scene," making it the most essential part of the narrative. As the concept of narrative peaks expanded into other fields, it is no longer restricted to drama. Instead, it became a flexible term applied across various domains such as film studies [32], cinematography [19], comics [30], and script studies [68, 93]. However, the definitions of narrative peak vary between different scenarios, such as "the height of narrative tension" [31], or "a turning point" [38], and "the most intense part of the conflict" [16]. Overall, despite these differences, there is a general consensus that the narrative peak represents the most emotionally impactful and engaging moment of the story [77].

From a cognitive theory perspective, narrative peaks function as cognitive anchors by converting abstract concepts into vivid experiences during moments of heightened tension or emotional resonance [91, 128]. These peaks stimulate anticipation and curiosity [83], which drive emotional engagement [20] and modulate attention [13], helping the audience maintain focus. By influencing attention, curiosity, and emotion, peaks serve as cognitive scaffolds that organize and enhance the retention of associated information [11, 124]. Information tied to these emotionally charged moments is further reinforced by memory consolidation [90], leading to improved long-term recall.

However, though the narrative peak is always considered the most crucial part of the narrative structure [31], there are only a few studies that focus on how to use it. Some linguistic researchers have explored narrative peaks, developing techniques to enhance speech quality and textual features to evoke emotions [71, 76]. Cohn (2015) also examined comic peaks, showing that coherence peaks significantly impact reading time [35]. Most importantly, in practical applications, few studies investigate how narrative peaks can make science communication more engaging and improve the effectiveness of information transmission in the OSV domain, despite their proven impact on attention, emotional arousal, and comprehension in other fields. There are many opportunities to explore and further develop narrative peaks and related strategies to enhance knowledge delivery.

2.3 Narrative Strategies in Online Science Videos

Previous communication studies has proposed various narrative strategies to enhance the quality of science video scripts or texts through three main approaches: creating memorable points, evoking emotions, and sparking curiosity. The first approach focuses on refining language by condensing core ideas into "succinct, compact ideas" [49, 94]. The second approach involves embedding emotional elements into the content, particularly strong emotions. By incorporating positive emotions, such as hope [55, 130], or negative emotions like sadness or fear [53, 66, 111], science videos become more engaging, credible, and appealing [135]. Lastly, sparking curiosity is an effective strategy for capturing audience attention [49, 94]. This is often achieved by creating "hooks" through raising thought-provoking questions [115], which can encourage viewers to reflect on and discuss the scientific topics presented [135].

Most studies on narrative structures or strategies in OSVs utilize methods such as case studies [17, 94, 126], content analysis [66, 94], literature reviews [49, 66], theoretical analysis [57, 99] and interviews [132]. These studies primarily examine the relationship between narrative strategies and video popularity [66, 131] or audience engagement [43, 47, 95, 135]. While some research examines the impact of narrative strategies on information delivery and learning outcomes [39, 41, 57, 67], few studies provide empirical evidence, with only a few focusing on comparisons between narrative and

expository styles and narrative perspective's [86, 114] influence on memory retention [17]. There is a significant gap that requires empirical research to systematically explore narrative strategies' influence on knowledge delivery and the viewer's memory and attention, especially since creating engaging content to effectively communicate knowledge to the general public is the core purpose of OSVs.

In addition, few studies on OSVs have delved into how the discourse within specific parts of the narrative structure affects engagement and information retention. Limited prior research has explored the concept of narrative peaks, which are the most impactful and critical moments within the narrative [29]. One study analyzed OSV narrative plots, emphasizing the dramatic methods and climactic elements, such as attention-grabbing openings [94] is frequently used by the creator of OSVs. Another study mentioned the "aha moment," where the problem is revealed at the end, which is described as "intellectually satisfying" for viewers [132]. However, these studies focus on the creator's perspective, failing to subjectively assess what constitutes a peak from the viewer's perspective which may not always match the creator's intent. Therefore, a stronger and more systematic investigation and empirical validation are urgently needed to explore how to create more engaging narratives involving narrative peaks to enhance knowledge dissemination and learning outcomes from both the creator's and viewer's perspectives. Through this, we can bridge the conceptual gap between existing science communication literature and the HCI community's focus on designing computer-mediated technologies and content [114, 132].

3 DEFINING A DESIGN SPACE FOR CREATING ENGAGING KNOWLEDGE COMMUNICATION CONTENT WITH NARRATIVE PEAKS

Firstly, we aim to develop a comprehensive design space of narrative peaks in OSVs; we adopted a mixed-method approach combining theoretical and empirical results (**Figure 3**). We focused on the following three RQs:

RQ1: *What narrative peak strategies for online knowledge communication learning content are identified in existing literature?*

RQ2: *What additional narrative peak strategies can be observed in real-world examples of online science videos?*

RQ3: *How can these strategies from literature and real-world examples be unified and categorized to create a comprehensive design space for narrative peaks for science communication?*

3.1 Method: Step 1 - Develop a Codebook through Literature Review

3.1.1 Paper selection. We first conducted a literature review in related fields, such as communication studies, education, psychology, and HCI, to identify peak strategies proposed by previous studies that enhance effective knowledge delivery. We primarily searched for keywords such as "narrative of learning content," "online learning narrative design," and "narrative peak" in Google Scholar, the ACM Digital Library, and the IEEE Xplore Digital Library. However, the literature does not clearly define narrative peaks for online learning videos. Thus, we broaden our search to the discussion of the narrative or narrative design of learning content in general. We finally chose 34 papers across education (4), psychology (3), communication studies (22), and HCI (5) that are highly relevant to our research. They are chosen because they focus on methods and strategies for designing narratives that potentially improve information delivery in online learning videos [43, 49, 94], as well as their insights into creating more engaging and higher educational texts [29]. Additionally, some of the papers explore related fields, such as the analysis of narrative peaks in data videos [133] or documentaries [77].

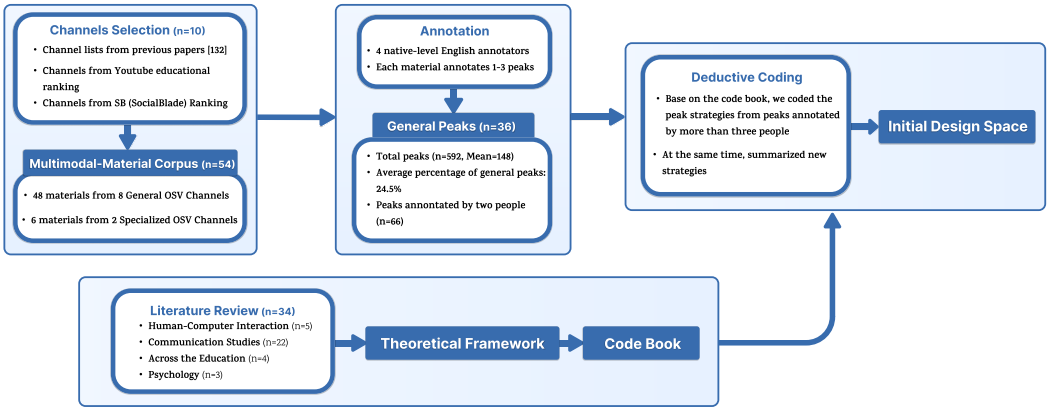


Fig. 3. Our design space was developed in two stages. (1) In Stage 1, we first conducted a literature review to create a strategy codebook. (2) In Stage 2, we created our own OSV corpus and asked our participants to annotate the peaks they identified in the provided content. We then conducted a content analysis using deductive coding method [103] based on the strategy codebook from Stage 1 to create a design space.

3.1.2 Code Development. Two authors participated in the coding of these 34 papers. The primary objective was to identify potential peak narrative strategies for learning videos mentioned in these previous studies. Initially, each author independently reviewed all the selected papers, focusing on content related to narrative strategies or structures that enhance learning outcomes—such as knowledge retention, recall, focus, engagement, and curiosity. Relevant content was then extracted and compiled into a consolidated document. Subsequently, using an open coding approach [15], two authors independently identified and coded key strategies, including their definitions and relevant contexts within the selected content. Following this, the two authors engaged in multiple discussion sessions to reconcile differences and reach a consensus on the coding. This collaborative effort culminated in the development of a codebook with 11 strategies (**Table1**) for narrative peak strategies in OSV learning content.

3.2 Limitations of Developing a Codebook through Literature Review Only

In the process of coding the 34 papers, we have discovered a few key limitations of the existing literature. (1) There is a lack of comprehensive studies on narrative peaks in online learning content, not to mention the narrative design of OSV. This limitation restricts our understanding of how to create effective learning content by incorporating narrative peaks. (2) Furthermore, the strategies from the literature primarily focus on content creation, specifically on how content creators can craft better narratives. However, science communication encompasses not only the dialogue model, where scientists explain their work in an understandable way to a passive audience but also the public engagement model, which focuses on involving the public in scientific activities [92, 132]. Therefore, we also need to consider the viewer's perspective and explore what strategies the viewer perceives as effective. (3) The relevant papers primarily come from the field of science communication, with discussions typically focusing on theoretical aspects. These strategies lack empirical research validation to confirm their effectiveness, such as whether they actually enhance knowledge transmission (e.g., viewers' willingness to watch and engage with the content and their memory retention of the conveyed knowledge). (4) Since the existing studies about narratives of online knowledge content are mainly theoretical, the strategies derived from them lack corresponding examples in specific OSVs.

To address the limitations found in the existing literature, we created our own corpus of OVSs and asked our participants to annotate their perceived peaks in the next step of study 1. This step will allow us to create a design space that is more practical and readily applicable. Using the initial 11 strategies derived from the literature as our codebook, we conducted deductive coding on participants' annotating results to develop a more thorough version of the design space. This theory and practice combined approach will also help us better answer RQ2 and develop a more detailed and practical understanding of narrative peaks in OSVs (RQ3).

3.3 Method: Step 2 - Viewer-Centered Annotation Process

To better understand what constitutes a peak in OSV learning content, we adopted a viewer-centered approach [77], previously used to study peaks in documentaries. By "viewer-centered approach", we refer to examining the viewers of OSVs' subjective perceptions of what they consider to be peaks. This method allows us to investigate peaks from the viewer's perspective, offering insights into what elements resonate most strongly with the audience. Four annotators were involved in the process of annotating the peaks. Subsequently, three authors (coders) conducted a content analysis of the annotated peaks marked by at least three annotators to identify the strategies and contextual information. Afterward, we used the acquired empirical data to refine the existing design space.

3.3.1 Online Science Video Corpus Making. Since we aimed to have viewers annotate peaks from their perspective, focusing solely on the narrative, and there was no suitable dataset available for OSV videos, we decided to create our own OSV corpus. The following section outlines our dataset selection process and key considerations in the creation of the corpus.

Channel Choosing. We identified popular and influential educational science channels by leveraging previous research, rankings, and comprehensive online databases. This approach ensured that the channels selected were not only well-received by audiences but also represented a broad spectrum of content and presentation styles with high quality. Our selection process involved reviewing studies on OSVs [132], examining YouTube's Top 150 "education channels" [3], and analyzing the Top 150 educational channels as ranked by SocialBlade [2]. In terms of popularity and diversity, we chose well-known channels with millions of subscribers, such as Vsauce, TED-Ed, Vox, MinuteEarth, Be Smart, and Sprouts. These channels are not only popular but also exemplify different methods of science communication, ranging from thought-provoking interdisciplinary content to animated educational videos and data-driven explanatory journalism. This selection provided a rich and varied landscape of educational science content for our analysis. We finally selected 11 channels.

Video Choosing. For videos we chose six videos from general channels(n=8) with diverse content, ensuring topic variety within each channel. For specialized channels (n=2) (e.g., psychology-focused), we selected three videos to maintain a balanced representation. To ensure diversity in content and presentation, we included videos from creators across North America, Europe, and Asia, showcasing a variety of perspectives and narrative approaches. The selected videos featured presenters of different genders, ethnicities, and age groups, covering a wide range of topics, including natural sciences, social sciences, technology, and interdisciplinary subjects. The presentation styles varied from animation and live-action to mixed media and presenter-led formats.

We selected videos typically 4-6 minutes long, in line with research suggesting 6 minutes as an optimal duration for OSVs [60]. Each video contains at least one core knowledge point and follows a narrative format, presenting a spoken or written account of connected events in sequence.

This resulted in 54 videos (**Example in Figure 2**) from 10 different channels. This varied collection provides a solid base for analyzing narrative strategies and key moments in OSVs across

topics and presentation styles, offering insights into effective science communication techniques in the online video format.

Material Creation. In order to emphasize our focus on narrative peaks, we opted for an annotation approach that utilizes both audio and onscreen captions in a multimodal format, deliberately excluding other visual components (such as graphs or talking heads). This decision aims to minimize visual distractions that could potentially affect the viewer's perception of the narrative and the memorability of information, considering the viewer's perceived narrative peak from a narrative perspective. We re-created versions of these multimodal learning materials with new audio and captions without any visuals to serve as our annotation corpus. Drawing on cognitive psychology and psycholinguistics, this approach allows us to explore how narrative structure influences cognitive load and memory without the additional demands of visual processing [124]. This methodology also aligns with established practices in psycholinguistics, where text or audio stimuli are often used to study language processing, comprehension, and memory [70, 72, 107]. Although visuals were omitted, the study retains ecological validity as it reflects how many people consume online content — multitasking or relying on audio and captions without always watching the screen. This method also provides a robust foundation for understanding the linguistic and auditory aspects of narrative peaks, which can serve as a basis for future research incorporating the complexities of visual elements.

3.3.2 Annotators. In terms of annotators, we require individuals with a background in linguistics or journalism to ensure a better understanding of material narrative design. Finally, the group consists of four individuals, comprising two women and two men, with an average age of 22.25. The annotators are all native-level English speakers recruited from the university community, with a LexTALE score [79] of 84%. They have academic backgrounds in Linguistics & Translation, English Language & Literature, Data News, and International News.

3.3.3 Annotating Process. We began with a pre-training session where participants received instructions using two videos. Annotators were instructed to mark the moments where they felt the highest tension and high arousal levels, attention, and the most impressive. They were not supplied with an explicit definition of a narrative peak. Instead, all annotators needed to form independent opinions of where they perceived narrative peaks. Annotators used the ELAN annotation tool during the viewing process to annotate the peaks. After watching the videos, they revisited and confirmed their selected 10-second narrative peaks. We ensure they know how to use this tool in pre-training sessions. After the pre-training session, four annotators were asked to each watch and annotate 0-3 peaks in each material, with each peak lasting 10 seconds. All participants watched all of 54 the videos. The order of the videos was counterbalanced.

3.3.4 Content Analysis of the Narrative Peaks. For content analysis, we focused on narrative peaks identified by at least three out of the four annotators. Following a previous study's strategy [77], we considered two peaks overlapping by at least 2 seconds as the same peak. Given that merged peaks could potentially have a longer duration, we refer to the context and extract a separate segment of text. For example, if two annotators have marked content in consecutive sentences with some overlap, we will take both sentences and treat them as a single peak [77]. This selection process finally results in 36 peaks marked by 3 out of 4 annotators, and we call these peaks "general peaks".

During the content analysis process, three authors participated in the deductive coding process as three coders. Initially, two coders collaboratively reviewed and coded 10 peaks to establish a consensus for the coding process. The deductive coding [103] was guided by an initial codebook derived from previous literature. In this phase, we focused on identifying specific strategies employed in narrative peaks, categorizing and defining these strategies, and determining their application

areas. We also assessed whether the peaks were tied to specific knowledge points and explored how these strategies could be applied in text editing to enhance information or knowledge delivery. This included adding content, adjusting structure, or revising existing material. Additionally, we considered the potential positions where these strategies could be most effectively implemented.

Subsequently, the two coders independently coded the remaining 26 peaks, achieving a high inter-rater reliability of 92.5% [88]. A third coder was then brought in to assist in refining the codes and terms. The three coders held several meetings to develop and fine-tune these codes and terms, striving for consensus on the definitions and classifications of the peaks, the strategies employed, and the content features relevant to each type of peak. The third coder also analyzed the differences and similarities between frequently occurring peak strategies and those outlined in the codebook developed in step 1. Together, the three coders reviewed and selected newly identified strategies, resulting in a comprehensive design space supported by specific examples from our corpus and contextual information and more practical guidelines of how to use the peak strategies in the design space.

Table 1. Coding book derived from literature review

Strategies	Details
(1) Opening with the core idea	Involves starting with the main concept to engage the audience immediately [49, 126].
(2) Summarizing the key knowledge	Provides a concise overview of essential information [94].
(3) Adding anecdotes	involves including fact-checked short incidents to clarify concepts and capture attention [78, 82].
(4) Using metaphors	Utilizes metaphors to create vivid mental images, aiding understanding and memory retention [43, 49].
(5) The moment of change	Such as the "And, But, Therefore" (ABT) Storytelling structure" highlights disruptions in the narrative to clarify insights [49, 66, 101].
(6) Showing accumulative significance	Demonstrates the importance of using stacked data or facts to create a lasting impression [134].
(7) Evoking positive emotion	broadens an individual's thought-action repertoire, promoting creative and expansive thinking [49, 55, 57, 94, 113, 130].
(8) Evoking negative emotion	Narrows down the focus of attention by emphasizing specific actions or stimuli; this heightened focus often leads to better recall [49, 57, 66, 94, 111].
(9) Dramatic questions with answers	Sets the narrative tension and creates a narrative appetite, fueling the audience's desire to know more [49, 66, 73].
(10) Inquiry and Reveal	Starts with a question and reveals the answer at the end, piquing the viewers' curiosity [132, 135].
(11) Adding visual descriptions	Using concrete visual language, which is more memorable than abstract text to enhance knowledge acquisition [6, 49, 57]

3.4 Results: Defining the Design Space for Peaks in Knowledge Communication Narratives

3.4.1 Codes from Literature Review. Through open coding of selected literature, we have identified 11 key strategies as our initial codes. These codes are listed in **Table 1**.

3.4.2 Results of Viewer-centered Annotating Process. On average, each annotator identified 148 peaks across 54 videos. Among these, there were 66 peaks marked by two annotators) and 36 peaks marked by three or more annotators, which accounted for 24.5% of the total.

These 36 peaks marked by three or more annotators were used for deductive coding based on a codebook derived from the previous literature review. Through iterative discussions, 19 strategies were identified, each with detailed definitions, specific usage contexts, and clearly defined functions. These 19 strategies were categorized into six dimensions (**Table 2**). We found that all 11 strategies from the codebook were identified through content analysis. Building on this, we refined the definitions of these 11 strategies, introduced 8 newly discovered ones, and provided practical guidance on their application.

In our deductive coding, we also found that a single peak often involves the combined use of multiple peak strategies, falling under several strategy categories. We will discuss each of these strategies and which strategies often use together in detail in the following sections(Based on the results from the workshop in Study 2, we later merged the 19 strategies to 16 strategies that had similar functions and usage pattern, please refer to (**Section 5.5.5** and **Figure 1**).

3.4.3 Overview of the Initial Design Space. Our design space is divided into six dimensions, based on the levels of linguistic objects as defined by the text hierarchy [36, 42]. These levels include: Word Level, Sentence Level, Paragraph Level, and Structural Level. Many scholars in creative writing and text processing argue that texts are "hierarchies of content objects" [36, 42], meaning that texts are composed of nested linguistic units such as words, sections, and paragraphs[109]. Based on these linguistic objects, various theories have categorized and organized them hierarchically from smaller to larger units [26, 64, 123] to ensure clarity and coherence in writing. We adapted these classifications to categorize the strategies within our design space. The classification criteria are based on how these strategies impact the narrative of the entire OSV script, focusing on whether the adjustments are at the word, sentence, paragraph, or overall structure level. The specific definition and function, example, and guideline for each strategy are as follows:

Dimension 1: Precision Language Optimization (Word and Sentence level) This dimension's strategy primarily involves precise adjustments to the wording, utilizing metaphorical language to convey complex ideas through relatable comparisons, humorous expressions by selecting amusing or unexpected words, multiple transition signals, or repetition of key terms to emphasize essential knowledge points and make the content more engaging and relatable.

(1) Use metaphors:

Definition and Function: Utilize a suitable metaphor with familiar comparisons to further explain the key knowledge point; this peak strategy aims to assist the audience in understanding the key knowledge better. Using metaphor can help communicate information through affective imagery that evokes associations and relevance to the audience's lives [49].

Example: This strategy could be short narratives or expository content. For example, in a material titled "The Disease You Will Never Survive", to emphasize the rarity of contracting Creutzfeldt-Jacob disease, the author uses a vivid metaphor: "*But don't freak out, Creutzfeldt-Jacob disease is extremely rare; it's about as common as being struck by lightning.*"

(2) Use humor:

Table 2. The levels, dimensions, 19 peak strategies, and frequency of occurrence within each identified peaks in our OSV corpus. See the corresponding definitions, functions, use tips, and examples in **3.4.3**.

Level	Dimension	Peak Strategy	Frequency
Word and Sentence Level	**Precision Language Optimization**	(1) Use metaphors [43, 49]	1
		(2) Use humor	1
		(3) Use multiple transition signal words together [49, 66, 101]	**7**
		(4) Repeat key point(s) or question(s)	3
Sentence Level	**Raise a Question**	(5) Raise a question with an answer [49, 66, 73]	**10**
		(6) Raise a question without an answer	3
		(7) Inquiry and reveal [132, 135]	1
Sentence and Paragraph Level	**Add Narrative Elements**	(8) Add stories	5
		(9) Add real-world supporting examples [78, 82]	3
		(10) Add an imagery description [6, 49, 57]	5
Structural Level	**Enhance Introductions and Conclusions**	(11) Open with the central theme [49, 126]	**7**
		(12) Define key terminology at the beginning	**7**
		(13) Summarize the key knowledge at the end [94]	3
Structural Level	**Make Strategic Content Transitions**	(14) Shift between pros and cons	5
		(15) Bridge expository and narrative elements	2
		(16) Shift between two knowledge points	2
Any Level	**Evoke Emotional and Affective Engagement**	(17) Create quantitative emphasis [134]	**7**
		(18) Create negative emphasis for focused attention [49, 57, 66, 94]	2
		(19) Make positive emotion to expand action repertoire [49, 55, 57, 94, 113, 130]	2

Definition and Function: This peak strategy utilizes humorous expressions (e.g., puns) or words to emphasize the critical knowledge point and to make an impression. This strategy can serve as an interesting expository to add to the relatively complex and lengthy material that follows, creating a little break moment.

Example: This strategy is suitable for relatively dull or monotonous topics, as it helps to enhance their interest. For example, the material "Why Do Our Noses Stick Out?" The author uses a clever pun to amuse the audience, playing on the word 'nose' as a homophone for 'knows': "*So why do humans have noses that stick out, but other apes don't? Now, nobody 'nose' for sure, sorry.*"

(3) Use multiple transition signal words together:

Definition and Function: This strategy includes two key techniques. First, it involves the concentrated use of transition words, such as "and," "but," and "therefore," to highlight shifts in meaning or emphasize parallel structures. These transition words should be used in clusters within one or two sentences to create a significant cognitive impact, as simply using one or two is not enough to generate a peak. These cues act as cognitive markers, prompting the audience to pay closer attention and aiding in comprehension. The use of cognitive transition cues is often referred to as a "moment of change," in previous work.

Example: The material "The Science of Being Transgender" uses multiple signal words like "*but,*" "*and yes,*" and "*although*" to emphasize the critical differences between male and female brain structures: "*But sexual differentiation in a brain, actually happens much later than Gonadal Differentiation. And yes, although controversial Male and Female brains have structural and functional differences between each other.*"

Tip: Careful consideration is needed when applying these cues, as improper use can reduce narrative tension or create a convoluted flow. For example, the overuse of patterns such as "And, And, And" (AAA) or "Despite, However, Yet" (DHY) can lead to ineffective storytelling.

(4) Use repetition of key terms:

Definition and Function: This peak strategy involves repeating key terms to emphasize knowledge points to enhance memorability. It is purely expository in form, as repetition of specific words or phrases reinforces crucial information.

Example: The material titled "Why Is Yawning Contagious?" employs this strategy by reiterating the most important questions to emphasize key points and capture the audience's attention: "*Why do we yawn, and why is yawning contagious? How come seeing someone yawn or even thinking about it makes us want to yawn?*"

Dimension 2: Raise a Question (Sentence Level) This dimension is on the sentence level. Each strategy focuses on how a question is crafted and delivered within the bounds of one or a few sentences.

(5) Raise a question with an immediate answer:

Definition and Function: One common strategy observed in our annotated peaks involves asking a question at the beginning and immediately providing the answer to introduce key knowledge points. Often, a dramatic question is posed in the opening segment of the video, followed by the communicator offering a brief answer before gradually unfolding the story [135]. This method not only introduces the subject matter but also surprises the audience [49] by acting as an eye-catcher that instantly draws viewer's attention [94].

Example: The material "What the COVID vaccine does to your body?" sets a pair of question and immediate answer at the beginning to respond to the central theme: "*What good does having a tiny fragment of viral spike in your body do? It gives your body, and more importantly your immune system, a preview of what the virus looks like without causing disease.*"

(6) Raise a question without an answer

Definition and Function: This question is posed to the audience without the expectation of an immediate response and often recalls the central theme of the material, encouraging reflection and reinforcing key points. Unlike questions that offer answers, this approach emphasizes interaction with the audience, often "breaking the fourth wall" [21, 110], which effectively fosters emotional responses and encourages deeper reflection, thereby optimizing memory retention. By leaving thoughts unresolved, this strategy not only stimulates curiosity but also enhances critical thinking.

Example: In a material on "The Pygmalion Effect", the question at the end "*What do you think about this theory?*" prompts personal reflection. This approach deepens engagement and helps build a personal connection between the audience and the content, ultimately enhancing the learning experience.

Tip: The creator can use a question at the end of the narrative to pose a reflective question to the audience. This strategy is always presented in an expository format [66].

(7) Inquiry and reveal:

Definition and Function: Using this strategy, creators often employ an explainer format that begins with a "gripping question to create suspense," prompting viewers to seek answers with curiosity . The answer is then gradually revealed through explanations and examples at the end of the science stories leading to an "aha moment" that provides viewers with an intellectually satisfying experience [132, 135].

Example: Take the material "How to get better at video games, according to babies" as an example, the author puts a question at the beginning of the material: "*What was it that made this particular game so vexingly difficult for AI? And what would it take to solve it? "* However, the author

does not provide an immediate answer for suspense. After using narrative to explain how experts realized that solving some game problems requires AI to maintain curiosity about things. The author finally gives the answer and the end of the material - they are inspired by "babies": "*This is where "babies" come in. There just seems to be something intrinsically rewarding about novelty.*"

Tip: Our annotation process shows that strategy is typically presented in an expository format. This strategy is presented in an expository format, and commonly used in inquiry-driven videos [132]. Note that this strategy is often combined with strategies (11)"Open with the central theme" and (13) "Summarize key knowledge at the end".

Dimension 3: Add Narrative Elements (Sentence and Paragraph level) Narrative elements, such as plot, theme, scene, and imagery [44, 104, 125], are crucial in storytelling. These elements function both at the sentence and paragraph levels, creating a layered impact. At the sentence level, brief but vivid narratives, examples, and descriptions play critical roles in introducing or reinforcing key ideas. Each sentence acts as a separate unit that captures attention and conveys important concepts concisely. At the paragraph level, various narrative elements are interwoven to form a more complete and engaging story arc that unfolds over multiple sentences.

(8) Add stories:

Definition and Function: Story refers to a sequence of events or actions that unfold over time, involving characters, settings, and a plot [46], typically consists of a beginning, middle, and end [54]. These detailed narratives provide a comprehensive picture and stimulate the recipient's imagination, which helps to convey information and contribute to memory retention [49]. Adding a vivid story can significantly make the material easier to understand and more interesting so that it could increase the audience's attention during a long expository section.

Example: The material "ADHD from Childhood to Adulthood" introduces the obstacles that ADHD patients face throughout their lives. The author weaves the story of a girl named Lisa, allowing the audience to empathize with Lisa and gain a deeper understanding of the challenges faced by individuals with ADHD.

Tip: This strategy is well-suited for complex topics, such as Astrophysics, Biochemistry, or Psychology. Creators often use an extended narrative story to elaborate and explain deeply, such as a scientific discovery story [7]. Additionally, this strategy can evoke emotions and empathy through storytelling, which is why it is often used in conjunction with strategy (18) " Create negative emphasis for focused attention" and (19) " Make positive emotion to expand action repertoire".

(9) Add real-world supporting examples:

Definition and Function: This strategy involves incorporating relatable and vivid examples [78, 82] to clarify complex or abstract concepts difficult for the audience to understand. By providing a clear explanation, the audience could receive the knowledge better. Unlike strategy (8), this approach typically includes concise, short narratives or descriptions in 1-2 sentences—that effectively clarify and reinforce concepts.

Example: In the material "Why Are Things Cute?", the author explains the specific meaning of "cute" in ancient times, citing a real-world example from literature: "*"About 180 years ago, the word cute began to be used as slang for a girl, who was pretty.*" This example is simple but vivid to explain the origin of the term.

Tip: This strategy is well-suited for abstract or obscure concepts, using one or more brief examples relatable to the audience's daily life to elaborate and enhance understanding. It is essential to ensure that the added examples are connected to the core knowledge to avoid comprehension interference caused by irrelevant information [57].

(10) Add an imagery description:

Definition and Function: This strategy incorporates detailed descriptions of a scene or factual scenario to effectively engage the audience and create a stronger sense of visual imagery. This detailed description of scenes or imagined visuals is considered a narrative element in traditional drama and writing [45, 104]. As previous research indicates, concrete visual language is more memorable than abstract text [57]as they are particularly effective at eliciting mental imagery [6, 49]. Viewers from imagining these issues on their own, which should, in turn, enhance knowledge acquisition [57].

Example: The material "Why is The Universe So Empty?" depicts a universe far different from ours, vividly contrasting with it: "*Imagine a different universe from our own, where all the matter is spread out, perfectly smooth and uniform... then everything would be pulled to the center and would end up clumped in one place.*"

Tip: This peak strategy is usually used to describe the details of an unusual scene in life, such as an endangered animal or a hypothetical scenario.

Dimension 4: Enhance Introductions and Conclusions (Structural Level) This dimension focuses on enhancing introductions and conclusions that directly impact the framework and organization of the content, ensuring that information is presented in a logical and structured manner.

(11) Open with the central theme:

Definition and Function: Opening with the central theme is a strategy that presents the main topic right at the beginning, establishing a clear narrative structure. This often involves a concise explanatory introduction or a brief narrative that integrates with the expository text, serving as a compelling "hook" to engage the audience [49]. The goal is to immediately capture attention while providing a framework for the information to follow.

Example: In the video "What If Humans Disappeared?", the opening describes what the world would be like without humans, blending narrative and factual elements to introduce the topic in an engaging way. This strategy enhances learning by creating a structured starting point, making it easier for learners to organize new information.

(12) Define key terminology at the beginning:

Definition and Function: This strategy focuses on explaining complex or uncommon terms at the outset, giving the audience the pre-knowledge needed to understand the main content. Unlike the narrative approach of introducing a theme, this method is more expository, directly clarifying terms that might otherwise confuse the audience. By reducing cognitive load, as supported by Cognitive Load Theory [124], this strategy allows learners to focus on the core content without getting distracted by unfamiliar terms.

Example: In the video "What is Cool?", the term "cool" is defined in simple language: "*Cool is a judgment of taste. People who are cool exhibit a style others want to emulate.*" This early clarification helps viewers better engage with the material that follows.

(13) Summarize key knowledge at the end:

Definition and Function: Summarizing key knowledge at the end of a video helps reinforce the material and enhance memory retention. This strategy involves concisely retelling the main points, typically in an expository form, to strengthen the audience's understanding. It taps into the "recency effect" [9], where the information presented last is more likely to be remembered.

Example: In the material "What Causes Economic Bubbles?", the video concludes by summarizing the key events that led to the burst of economic bubbles: "*Suddenly the demand ended. Prices plummeted, and pop! The bubbles burst, and the market crashed.*" This clear recap consolidates the audience's knowledge, making it easier to recall and apply later.

Dimension 5: Make Strategic Content Transitions (Structural Level) This dimension encompasses techniques that introduce significant shifts or transitions in content structure, perspective or focus to maintain cognitive engagement and facilitate information processing. These strategies typically appear in the form of several sentences, signaling to the viewer that the content is transitioning to the next stage. The strategies in this dimension (strategy (14), (15), and (16)) are often used in combination with strategy (3) " Use multiple transition signal words together".

(14) Comparative transition between pros and cons:

Definition and Function: This strategy deliberately transitions between contrasting viewpoints or aspects of a concept, often alternating between advantages and disadvantages. Such a peak typically occurs in an expository format, usually placed in the middle of a key knowledge point.

Example: In the material "The Power of the Placebo Effect," the author first introduces the positive outcomes of the placebo effect, then shifts perspectives with a clear sentence: "*So shouldn't we celebrate the placebo's bizarre benefits? Not necessarily.*" The following section highlights the negative impacts of the placebo effect. This structure plays a significant role in the material by clearly marking the duality of the concept and acting as a pivotal point, facilitating audience retention.

Tip: When applying this strategy, creators need to clearly separate the pros and cons of the subject matter, then introduce a signal or emphasis expository sentence that serves as a transitional structure between the two.

(15) Structural bridge between expository and narrative:

Definition and Function: This strategy sets transitional sentences between narrative and expository elements and serves as a clear hint. It helps to leverage the strengths of both narrative engagement and expository clarity.

Example: In the material titled "What Causes Economic Bubbles?", the author uses the well-known story of Dutch tulips to explain the economic bubble phenomenon. The author introduces a hint to highlight the connection between the theoretical concept and the story with the following sentence: "*Economists call this a bubble. So what exactly is going on with a bubble? Well, let's start with the tulips to get a better idea.*"

Tip: This strategy is suitable for knowledge points that combine narrative and explanatory elements, especially for longer content. Creators need to separate the narrative and explanatory sections and add a transitional sentence in between as a bridge and a hint to connect the two parts.

(16) Shift between multi-perspectives:

Definition and Function: This strategy introduces a deliberate shift between distinct but related knowledge points by using transitional statements or concepts that act as cognitive bridges to make the structure clearer.

Example: In the material "Water," which presents some lesser-known facts about water as a common element in daily life, the topic of hydrophobia is discussed, particularly in animal groups. After explaining hydrophobia, the author uses this sentence as a transition: "*One final note on hydrophobia—it can happen in humans." This smoothly leads into a discussion about the Rabies virus.*"

Tip: This strategy is useful in materials that are primarily expository or cover multiple knowledge points. Creators can first list the knowledge points and place a clear connecting sentence between them, which is always presented in an expository format, serving as a bridge between ideas.

Dimension 6: Evoke emotional and affective engagement (Any Level) This category encompasses strategies that leverage the interplay between cognitive processes and emotional responses to enhance learning engagement and knowledge retention in science communication. It involves the deliberate structuring and presentation of information to create both cognitive tension and emotional arousal, which strengthens the activation of neural connections and therefore leads to a

more vital consolidation and better knowledge acquisition of learning content [54, 57]. Strategy in this dimension can be applied at any structural level because emotions can be triggered through a single powerful word, a sentence that introduces an emotional concept, a paragraph that builds emotional tension, or the overall structure that gradually leads to an emotional climax.

(17) Create quantitative emphasis:

Definition and Function: This strategy includes two key elements: data emphasis and linguistic intensification. Data emphasis deliberates presentation of massive statistical data to provide concrete evidence and create a sense of scale or magnitude. While, linguistic intensification is the use of vivid, emotionally charged vocabulary and phrases (e.g. the biggest, extensive large-scale) to heighten the impact of the information presented [134]. This strategy creates an emotional climax (which can be both positive emotion and negative emotion) in data-driven narratives.

Example: Take the material "What If Humans Disappeared?" as an example, the author uses many intuitional data, and exaggerated adjectives to depict the chaos Earth might face if humans were to disappear: "*Within hours, power plants would run out of fuel and shut down. As lights go out and electric fences lose their sting, over one and a half billion cows, nearly a billion pigs, and more than 20 billion chickens will break out of their enclosures, desperate for food.*" This layering of information strongly engages the audience's emotions, leaving them surprised and more attentive to the key point.

Tip: The peak presents in expository or expository with narratives, only suitable for materials that use extensive data to substantiate the knowledge point. This strategy is more limited in its use. Creators need to list the data from the material and exaggerate its expression, and if necessary, combine it with narrative elements.

(18) Create negative emphasis for focused attention:

Definition and Function: This strategy involves presenting dramatic, adverse outcomes to evoke strong negative emotions, narrowing attention focus, and enhancing memory for specific details [57]. Negative emotions, such as fear or sadness, tend to focus attention on specific stimuli, resulting in improved recall for emotion-congruent information [57]. Research on negativity bias in attention and memory [111] also supports this effect.

Example: In "Chesterton Fence: Don't Destroy What You Don't Understand!," the author illustrates the concept using the Great Chinese Famine, where an attempt to eliminate sparrows caused an ecological disaster. This outcome serves as a powerful warning, effectively evoking strong negative emotions and reinforcing the central message.

Tip: This strategy is only suitable for negative-themed content and is typically presented through a narrative format.

(19) Make positive emotion to expand action repertoire:

Definition and Function: This peak strategy employs encouraging language, typically towards the end of the material, and is especially effective when the climax or ending leaves the audience with an uplifting impression and reflection [94]. Positive emotions cause recipients to become more open to new experiences and more willing to approach and explore novel objects, people, thoughts, and behavior by broadening their breadth of attention [53, 57]; positive emotion also has long-term benefits and expand an individual's thought-action repertoire [49, 55, 113, 130].

Example: Take the material "You Don't Type Alone" as an example. The author initially discusses how our daily typing activities don't contribute significantly to calorie burning. However, in a surprising turn at the end, the author says, "But don't be discouraged, because typing and texting can bind us together." This statement serves to motivate the audience by highlighting the positive and connective aspects of typing.

Tip: This strategy is usually suitable for negative-themed content and is typically presented through a narrative format.

In conclusion, the initial design space for peak strategies, along with their corresponding definitions, functions, examples, and tips, has been outlined above. All these strategies follow the levels they were categorized into. However, there are many cases where strategies are used across levels, as peaks are not singular or mechanical. They need to be adapted based on the context and the specific knowledge points being communicated.

4 STUDY 1: INVESTIGATING THE IMPACT OF PEAK STRATEGIES ON LEARNING OUTCOMES

While many studies in educational content design conclude with theoretical frameworks or qualitative assessments, we sought to empirically evaluate the effectiveness of peak strategies identified in our previous studies. Specifically, this study addressed the following RQ.

RQ4: *How do different types of peak strategies in narrative content impact viewers' memory retention, enjoyment levels, and perceived cognitive load, compared to content without peak strategies?*

However, in designing our study, we encountered several methodological challenges:

(1) **Subtle effects:** Some strategies, particularly those at the word or sentence level, produce changes too subtle to measure effectively when applied in isolation, even in short narratives of approximately 150 words.
(2) **Scale:** Testing all 19 strategies individually would be impractical within a single experiment due to the extensive resources required.
(3) **Ecological validity:** In real-world applications, multiple strategies are often employed in combination rather than in isolation.

To address these challenges, instead of focusing individual strategies, we adopted a dimensional approach. Each dimension from our taxonomy was treated as an experimental condition. For each narrative, we applied all applicable strategies in a proper way within a given dimension in combination, comparing the results to a control text without these strategies.

This approach offers a pragmatic compromise between detecting meaningful effects and maintaining some level of ecological validity. While it limits our ability to isolate the effects of individual strategies, it allows us to evaluate the collective impact of strategies within each dimension. The examples of the modified texts used in the experiment are presented in the **Appendix C**.

4.1 Participants

We recruited 16 participants (5 male, 11 female) from the university community. The average age of participants was 26.93 years. All participants were either native English speakers or possessed native-level proficiency, ensuring they could easily read and comprehend the English materials.

4.2 Apparatus

4.2.1 Narrative Materials. We selected 12 for our experiment: 6 from our OSVs corpus, which have not been recognized as peaks by more than two people used in Study 1 and Study 2, and 6 sourced from online GRE practice exercises [58, 107]. The reason for selecting two texts is to test whether our approach can be transferred to other texts that focus on knowledge dissemination and not just be limited to our OSV corpus, as creators typically only collect knowledge-based materials and then process them when creating OSV narratives. For the materials within our corpus or GRE, we have ensured that the basic comprehension difficulty level and the word count are almost consistent. The OSVs corpus had an average length of 201 words (SD = 6.63) and a Flesch-Kincaid grade [118] of 10.43 (SD = 1.01), which means this material's reading level is appropriate for someone in the 10th grade. The materials from our OSV corpus covering fun facts such as reasons for yawning

and the development of the concept of 'cool'. The GRE averaged 168 words (SD = 16.97) with a Flesch-Kincaid grade of 14.7 (SD = 1.31), covering academic topics in Literature and Arts, Public Health, Biology and Earth Sciences, and Psychology. GRE passages were included to test high-level comprehension, cover diverse content, provide a neutral presentation without inherent peak features, and assess the transferability of our strategies to formal academic content.

4.2.2 Stimuli Production. As with the process of creating our own OSV corpus corpus, we aim to eliminate the influence of different visual effects on comprehension.We produced audio-visual stimuli with centered subtitles in Times New Roman font, size 72, primarily displaying two lines. The voiceover was generated using OpenAI TTS[102]. Baseline videos had an average duration of 121 seconds (SD = 4s), while edited videos averaged 128 seconds (SD = 5s). During the editing with peak strategies, we avoided adding too much content, ensuring that the differences in the duration of the stimuli with and without peak strategies were minimal, to clearly distinguish the impact of the peak strategies from any potential effects caused by extended learning time.

4.2.3 Task and conditions. We tested two factors: 1) the presence or absence of peak strategy and 2) the type of strategy. For the second factor, we collectively apply strategies from our six dimensions, each operating at different levels: *Precision Language Optimization* (Word and Sentence level), *Raise a Question* (Sentence Level), *Add Narrative Elements* (Sentence and Paragraph level), *Enhance Introductions and Conclusions* (Structural Level), *Make Strategic Content Transitions* (Structural Level), and *Evoke Emotional and Affective Engagement* (Any Level). One passage from a source was modified using all appropriate strategies from a dimension. An editor with over seven years of professional script writing experience edited the 12 passages based on these strategies to form the experimental group, with unedited versions serving as baselines.

4.2.4 Procedure. Participants watched videos. After each video, participants completed a questionnaire. Breaks were allowed as needed to avoid fatigue. The initial session lasted approximately one hour. Seven days later, participants took a recall test lasting approximately one hour.

4.2.5 Experiment design. We used a within-subject design where each participant watched 12 videos: 6 experimental (edited with peak strategies) and 6 baseline (without strategies). Both sets included 3 videos from the GRE corpus and 3 from the OSV corpus. The presentation order was randomized for each participant, with no more than two videos from the same condition or corpus appearing consecutively. Four different counterbalanced sequences were created to distribute strategy types evenly across GRE and OSV passages, with participants randomly assigned to one of these sequences. The experimental materials and baseline materials were also randomly shuffled during the viewing process. This design allowed us to isolate the effects of our peak strategies while minimizing confounding influences.

4.3 Measure

Our study employed a comprehensive set of measures to assess memory retention, enjoyment, and cognitive load. We organized these measures into immediate subjective experience tests and delayed memory tests.

4.3.1 Immediate Measures (Subjective Experience).

Cognitive Load: 5 questions adapted from NASA-TLX covered mental, physical, and temporal demands, effort, and frustration [65]. We refer the physical demand to adjusting posture, maintaining focus when watching the videos in the questionnaire design.

Enjoyment: 4 questions adopted from [40] measured the material's pleasurability and satisfaction.

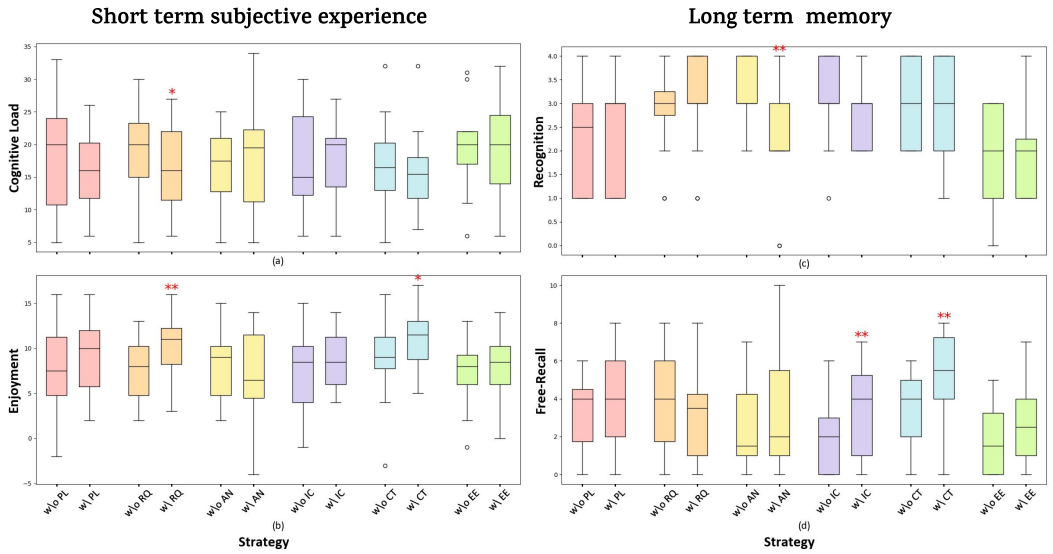


Fig. 4. Abbreviations for the strategies used in the figure: PL = Precision Language Optimization (Word and Sentence Level), RQ = Raise a Question (Sentence Level), AN = Add Narrative Elements (Sentence and Paragraph Level), IC = Enhance Introductions and Conclusions (Structural Level), CT = Make Strategic Content Transitions (Structural Level), EE = Evoke Emotional and Affective Engagement (Any Level). Asterisks indicate levels of significance: * denotes marginal significance ($p < 0.1$), while ** indicates significance ($p < 0.05$). (a) Cognitive load while watching the material (short-term); (b) Enjoyment while watching the material (short-term); (c) Delayed recognition (long-term); (d) Delayed recall (long-term).

4.3.2 7-Day Delayed Measures (Memory).

We employed three primary methods to investigate memory retention: recognition, cued recall, and free recall [52].

Free Recall: Participants orally retold all remembered points about each material's topic. Responses were recorded, transcribed, and scored (max 10 points).

Recognition: 4 multiple-choice questions (1 point each).

Cued Recall: 1 open-ended question about the main idea (5 points).

Scoring for Memory Tests: For the delayed memory tests, two authors developed a scoring rubric based on key knowledge points from the materials. To ensure reliability, two blind raters discussed the scoring criteria and independently scored 20% of the responses. The interrater reliability was high, with a correlation coefficient of 87%. After establishing this reliability, one rater proceeded to score the remaining responses using the agreed-upon rubric.

This approach allowed us to assess participants' immediate subjective experiences with the materials, as well as their delayed learning outcomes. Recognition tests indicate encoding [108], cued recall tests indicate storage [12], and free recall tests indicate retrieval ability [80]. The combination of immediate subjective measures and delayed memory tests provided a comprehensive view of the materials' effectiveness and impact on participants.

4.4 Results of Study 1

In our results, *Enhance Introductions and Conclusions* and *Make Strategic Content Transitions* strategies significantly improved memory performance in the free-recall test, while *Add Narrative*

Elements strategies performed poorly in delayed recognition(4 multiple-choice questions); The application of *Raise a Question* strategies marginally reduced cognitive load, while *Make Strategic Content Transitions* strategies significantly decreased frustration and effort, also enhancing enjoyment and engagement.

4.4.1 Analysis Methods. We compared evaluation scores between materials "with strategy" and "without strategy" for each strategy dimension. For normally distributed data (Shapiro-Wilk test, $p > 0.05$), we used repeated measures ANOVA. For data violating normality (Shapiro-Wilk test, $p < 0.05$), we employed the Wilcoxon signed-rank test. Figure 4 presents the overall results.

4.4.2 Immediate Measures.

Cognitive Load (NASA-TLX): Our analysis of cognitive load revealed several noteworthy findings. Applying *Raise a Question* strategies showed a marginally significant reduction in overall cognitive load ($p = 0.086$). When examining individual components, we found that applying *Make Strategic Content Transitions* strategies significantly decreased frustration levels ($p = 0.041$). Additionally, applying *Raise a Question* strategies led to a significant reduction in overall effort ($p = 0.010$).

Enjoyment: The enjoyment measures yielded positive results for multiple strategies. Applying *Make Strategic Content Transitions* strategies showed a marginally significant increase in overall enjoyment ($p = 0.099$), while applying *Raise a Question* strategies demonstrated a significant increase ($p = 0.048$). Further analysis revealed a marginal increase in pleasure level for applying *Make Strategic Content Transitions* strategy ($p = 0.066$), and participants were significantly less likely to lose track when engaging with material using the *Make Strategic Content Transitions* strategy ($p = 0.014$). However, we observed an unexpected significant increase in losing track for applying *Add Narrative Elements* strategies ($p = 0.032$), which warrants further investigation.

4.4.3 Delayed Memory Measures.

Recognition: In the delayed recognition test, we observed a significantly lower score for the *Add Narrative Elements* strategies ($p = 0.013$). This unexpected result suggests that adding narrative elements may have complex effects on long-term memory retention which require further exploration.

Cued-recall: Our analysis of cued-recall performance showed no significant differences across all strategies. This result indicates that the strategies may not substantially impact this specific type of memory retrieval.

Free-recall: The free-recall test revealed promising results for two strategies. Both the *Enhance Introductions and Conclusions* strategies and the *Make Strategic Content Transitions* strategies led to significantly higher recall scores ($p = 0.015$ and $p = 0.016$, respectively). These findings suggest that these strategies can effectively enhance long-term memory retention and improve overall learning outcomes.

4.5 Discussion of Study 1

In light of the results, we address **RQ4:** *How do different types of peak strategies in narrative content impact viewers' memory retention, enjoyment levels, and perceived cognitive load, compared to content without peak strategies?*

Our study reveals key insights into the effectiveness of narrative strategies in educational content. We found that strategies such as *Make Strategic Content Transitions* and *Enhance Introductions and Conclusions* can improve memory retention, as evidenced by the 7-day delayed free recall test. To our knowledge, this is the first quantitative evaluation of these strategies' impact on learning outcomes, providing valuable empirical evidence for their effectiveness.

Strategies related to *Raise a Question* effectively increased enjoyment and reduced cognitive load, enhancing the overall learning experience. However, contrary to expectations, several strategy dimensions presumed beneficial in literature, such as adding stories [78, 82], using metaphors [43, 49], and evoking emotions [49, 57, 66, 94, 111], did not show significant benefits. This unexpected result warrants further investigation on different materials with different topics and length.

Post-study interviews revealed mixed reactions, with some participants not noticing differences or finding the added strategies compelling. This suggests that strategy effectiveness may depend on personal relevance and implementation skill. Even with an experienced editor, achieving noticeable benefits proved challenging. For example, when we used the "Create quantitative emphasis" strategy to modify the text "How do wildfires affect animals," data stacking highlighted the disaster's severity. Three participants from the experimental group felt overwhelmed by the amount of data and only recalled the text's main theme in the free-recall test. However, one data-sensitive participant remembered specific details clearly.

These findings underscore the complexity of optimizing educational content design. The lack of observed benefits for some strategies highlights the importance of context, relevance, and skillful application. Content creators should be aware that even potentially beneficial strategies require careful implementation to maximize impact and avoid unintended consequences.

The varied responses emphasize the need for adaptive content catering to diverse learning preferences. Our study also reveals the need for more granular investigations into effective implementation of complex strategies and their interactions. To provide a more comprehensive view, we now explore how content creators perceive the value of these strategies, their utility, ease of application, and potential implementation challenges.

5 STUDY 2: EVALUATION WORKSHOP

We run workshop to evaluate and refine the design space comprising narrative strategies for enhancing OSV scripts and to address **RQ5:** *How do content creators perceive and experience the ease of implementation of various peak strategies in online science communication content?*

In particular, we have the following sub-goals in mind:

(1) To gather feedback from experienced content creators on the clarity, usability, and effectiveness of the proposed narrative strategies, and assess the practical applicability of the design space in improving OSV narrative design.
(2) To observe and analyze how experienced content creators interpret, select, and implement these strategies, including their decision-making processes and strategy combinations.
(3) To identify potential challenges, limitations, and areas for improvement in the design space, based on the participants' hands-on experience. This includes exploring the perceived benefits and drawbacks of using the design space for OSV script creation and editing.
(4) To understand how these strategies compare to, complement, or potentially enhance existing practices in science communication.

5.1 Participants

The workshop participants were selected to represent a diverse range of experiences relevant to OSV creation and narrative strategies. As shown in **Appendix A**, the group includes PhD students in Narrative Animation, Film, and Education; professional content creators including an OSV YouTuber and documentary makers; and individuals with linguistics and media backgrounds. Their experiences range from 3 months to over 5 years in relevant fields, providing a balance of fresh insights and seasoned expertise. By combining academic and practical experience among the

participants, we hope to provide a basis for evaluating the design space from multiple perspectives, potentially offering insights into both theoretical implications and practical applications.

5.2 Workshop Materials

To evaluate our design space and gather content creator feedback, we selected 12 pieces of material from our OSV corpus. These scripts were chosen specifically for their lack of obvious peaks, as indicated by previous annotation results. The materials averaged 197 words (SD = 12.5) and covered diverse topics including cultural evolution, environmental crises, and technological advancements. All materials were semantically complete with cohesive themes. The Flesch reading grades [118] of the materials ranged from 6.53 to 14.04, ensuring a diverse complexity level.

5.3 Workshop Procedure

The workshop was conducted online via Zoom in two rounds, each with 4 participants and lasting approximately three hours. The procedure began with an introduction to the design space, followed by a 20-minute familiarization period. Participants then had up to 100 minutes to edit the materials using strategies from the design space, with access provided through Google Docs and a Google Sheet.

Participants were tasked with improving OSV narratives to enhance memorability and viewer engagement. They were encouraged to modify the text by adding, removing, or restructuring content based on their interpretation of peak strategies. Given time constraints, each participant selected six materials based on their familiarity with the topics. The example editing results are shown in **Figure 6**.

Post-editing, participants completed a questionnaire assessing the usefulness and usability of the design space using a 7-point Likert Scale. The survey focused on three key aspects:

- Clarity of the design space
- Usability in script editing
- Effectiveness in enhancing knowledge conveyance and viewer engagement

Subsequently, semi-structured interviews were conducted, each lasting approximately 30 minutes. These interviews explored five principal areas:

(1) Strategy selection and application process
(2) Ease or difficulty in implementing strategies
(3) Challenges encountered and suggestions for improvement
(4) Prior experience with similar strategies in science communication
(5) Perceived benefits and potential drawbacks of using the design space for OSV script creation

5.4 Data Analysis

The data analysis process comprised two main components. Initially, one author quantified the frequency and co-occurrence of strategies employed during the editing process(**Appendix B**). Subsequently, the first and second authors collaboratively conducted a thematic analysis [18], systematically segmenting and grouping content creator feedback. To facilitate a comprehensive analysis, all workshop sessions and interviews were recorded. The survey results are in **Figure 5**.

5.5 Results of Study 2

5.5.1 Usefulness and Clarity of the Design Space. The design space's 19 strategies represent a significant advancement in structuring narrative approaches for narrative content in science and education. Participants reported that the design space effectively bridges the gap between abstract narrative concepts and their practical application. As noted in P3, this design space offers a detailed

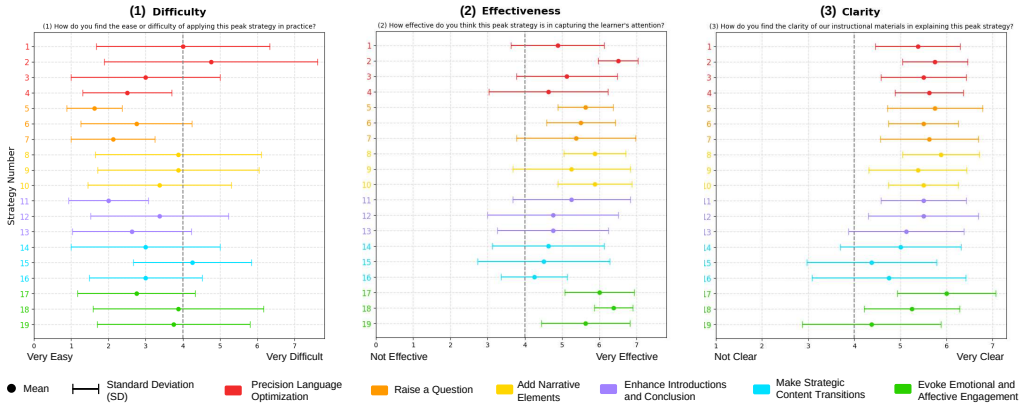


Fig. 5. Survey results: Evaluation of each strategy from three dimensions: difficulty, effectiveness, clarity.

guideline that not only highlights the appropriate strategies but also transforms what was once an instinctive writing process into a more structured and deliberate one. P2 commented, "*I found myself referring to the design space frequently, which is like consulting a dictionary during the revision process. It helped me think more systematically about narrative techniques, which had previously felt more like an intuitive, natural behavior.*"

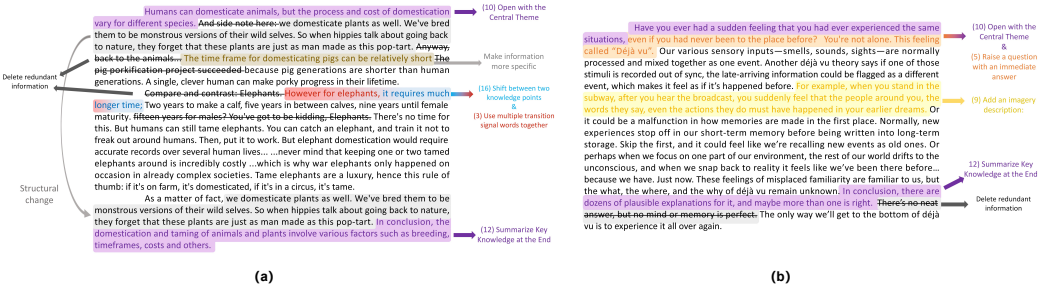


Fig. 6. Content creator' editing examples in our workshop based on our design space: (a) from P6, and (b) from P2.

On average, the guide scored above average for clarity (exceeding 4.375 out of 7 for each strategy), demonstrating that the design space did a relatively good job of translating abstract narrative concepts into more accessible guidelines. This also indicates that improvements can be made to revise strategies to make the updated version of the design space clearer.

Feedback about the text-heavy nature of the design space highlighted an important area for improvement. While the content was deemed valuable, participants suggested that its presentation could be optimized to enhance usability. In response to this feedback, we have integrated visual elements and interactive features in revising the design space, aiming to make it more user-friendly and engaging.

5.5.2 Varying Difficulty of Applying Strategies. A notable observation is the varying difficulty levels in applying these strategies. Certain strategies like "Use metaphors" and "Use humor" are perceived as more challenging (with mean difficulty scores of 4.75 and 4 out of 7 respectively), reflecting the complex cognitive processes involved in these creative tasks. While P3 highlighted their ability to connect with the audience's personal experience, P6 and P8 indicate that strategies "Add stories" and "Add examples" are difficult to apply effectively in a short period of time and require further investigation.

Conversely, strategies under*Enhance Introductions and Conclusions* and *Raise a Question* have lower difficulty scores (mean scores of 2.67 and 2.5 out of 7), suggesting they are more accessible entry points for improving educational narratives. The strategies within these two dimensions were also considered essential by P4 and P2, describing them as fundamental approaches. Importantly, these strategies also showed benefits in Study 1, making them highly valuable strategies to apply first.

Additionally, some strategies also demonstrate limitations in their usage. Compared to *Raise a Question*, *Enhance Introductions and Conclusions*, and *Add Narrative Elements* strategies, which are commonly applied across all types of texts, strategies in *Evoke Emotional and Affective Engagement* tend to be more suited for specific themes and emotionally charged content. For example, the strategy "Create negative emphasis for focused attention" was used by participants only twice in total. According to P5, this type of strategy is often more applicable to texts with a negative tone. As for "Create quantitative emphasis," as mentioned by P3, its use may depend on whether the subject matter of the text lends itself to an explanation through extensive use of data.

The difficulty level measure can help content creators consider cost-benefit rationales when applying these strategies. This information can also be used to develop AI-facilitated strategies to assist with more difficult modification tasks, enhancing the practical utility of the design space.

5.5.3 Combination of Strategies. To form one peak, we observed that some strategies are more easily applied alone, while others are often used in combination.

The most frequently applied strategy to form peak is "Use multiple transition signal words together," which was used 26 times both alone and in combination. Other commonly used strategies include "Open with the central theme," "Summarize the key knowledge at the end," and "Raise a question with an immediate answer," with frequencies of 15, 12, and 13 times, respectively. These frequently used strategies also show significance in Study 1.

In terms of combinations used to form a single peak, the frequent pairing of strategies in the *Raise a Question* dimension with *Enhance Introductions and Conclusions* (20 times in total) indicates a natural affinity between certain strategies, suggesting potential "best practices" emerging from the design space. Additionally, the strategy "Use multiple transition signal words together" in the *Precision Language Optimization* dimension is always used together with strategies in the *Make Strategic Content Transitions* dimension. For example, strategies in the *Make Strategic Content Transitions* dimension often focus on structural connections, and "Use multiple transition signal words together" can assist in transitioning towards the concluding content while keeping the viewer focused. This insight could be invaluable for developing more advanced guidelines or for training new content creators (**Appendix B, Table 5**).

5.5.4 Future Directions and Broader Applications. P8, P6 and P2 also expressed interest in automated editing tools based on the design space, pointing to its potential as a foundation for AI-assisted content creation. The desire for features such as post-drafting suggestions, structural adjustments, and assistance with challenging strategies indicates that the design space could serve as a knowledge base for developing intelligent writing assistants tailored to educational content.

According to the workshop participants, the applicability of our design space extends beyond OSV narrative creation. P6 also mentioned, "Last year, I spent two months preparing online learning materials to explain some educational content. Now that I see this design space, I realize many of these strategies could have been used at that time. It would have been great to have these strategies back then. The suggestion that the design space could be adapted to other fields(P2,P8), such as political speeches, highlights the design space's underlying versatility. This adaptability suggests that the principles captured in the design space may represent fundamental aspects of effective communication that transcend the specific context of educational videos. We will elaborate on these two aspects in the overall discussion at the end.

5.5.5 Improved Design Space. We further refined our design space with the following key changes based on participants' feedback. We added visual elements to our design space, making it easier to see where strategies are applied within paragraphs' beginning, middle, and end. Moreover, we defined the "Implementation Difficulty" of each strategy based on the workshop and interview results, categorizing them as "easy," "moderate," and "hard," with some brief explanations provided.

Through observing the participants' revision behaviors, we also merged the initial 19 strategies into 16 strategies.

Firstly, we observed that half of the participants (n=4) did not distinguish between the strategies of "Opening with the central theme" and "Define key terminology at the beginning". Instead, they viewed these approaches as a unified strategy, choosing between a definition or narrative based on the topic's nature. If the topic was complex, they opted for a definition, while for more familiar topics, they preferred a narrative opening to mention the theme. As a result, we merged these two strategies into one, calling it "Open with the central theme or definition." Similarly, for the strategies of "Raising a question with an immediate answer" and "Inquiry and reveal", most participants (n=6) did not apply them rigidly. They varied the positioning of the answer to fit the material's context, sometimes providing the answer right after the question and other times placing it later. They emphasized that sparking attention and curiosity through the question was the priority, while suspense was considered a bonus. Consequently, we combined these strategies into one: "Raise a question with an answer." Lastly, in our workshop results, strategies like "Add stories" and "Add real-world examples" were frequently used together (4 times), making up over half of their usage. P5 and P6 say they didn't differentiate between them in practice, with P6 stating, "I'm confused between these two strategies; they seem essentially the same." Both long stories and short examples enhance the narrative and provide vivid explanations and collect knowledge with the viewer. Thus, we merged the two into one strategy: "Add stories or real-world examples"

The final design space is shown in **Figure 1**, combining the findings of all studies.

6 DISCUSSION

Through a series of studies and investigations, we explored several research questions related to narrative peaks for online science videos(OSVs). Through an extensive literature review and content analysis, we developed a comprehensive design space for narrative peaks in OSVs. Our subsequent evaluation demonstrated that certain strategies, specifically those related to *Make Strategic Content Transitions*, *Enhance Introductions and Conclusions*, and *Raise a Question*, offer clear benefits in enhancing memory retention, improving enjoyment, and reducing cognitive load. Importantly, these strategies are relatively easy to apply, making them accessible tools for content creators to improve the effectiveness of their educational materials.

Interestingly, our research also revealed some contradictions with existing literature. Some strategies, despite being widely cited as beneficial, did not consistently show clear benefits in our

study. Moreover, we found that certain strategies can be challenging to implement effectively, especially for less experienced content creators.

Nevertheless, several insights emerge from our results to guide the practical application of these strategies.

First, combining strategies may be beneficial, given that different strategies excel in different areas. For example, *Raise a Question* enhances immediate experience, while *Enhance Introductions and Conclusions* and *Make Strategic Content Transitions* improve long-term recall. Combining these strategies might yield optimal results as they can promote coherent schema [129] formation and create cognitive arousal [116] during transitions, enhancing memory encoding and retrieval [87]. "Using Multiple Transition Signal Words Together" combined with *Make Strategic Content Transitions* as a structural transition is used together multiple times in Study 2. Still, excessive use of changes and content transitions should be avoided to prevent hindering the learning process, and transition can also be made through questions and summarizing [66].

Second, context matters. The effectiveness of strategies may depend on the content type and learning goals. While *Add Narrative Elements* showed some negative effects, it might still be useful in specific contexts or when applied differently. Strategies such "Add stories or real-world examples" and "Add an imagery description" should be linked to knowledge points and connect with participants' personal experiences while avoiding the introduction of irrelevant stories that may disrupt the understanding of the core knowledge points [57]. Similarly, content analysis results in OSV corpus and empirical data Study 2 suggest that strategies in *Evoke Emotional and Affective Engagement* are highly dependent on text characteristics. For example, whether the subject matter is suited for large amounts of data to capture attention, the use of negative emotions to induce focus, and the activation of positive emotions to call for action all require careful contextual analysis.

Third, cognitive load and enjoyment are important factors. Strategies that reduced cognitive load and increased enjoyment such as *Raise a Question* and *Make Strategic Content Transitions* seemed to have broader positive effects, highlighting the importance of these factors in content design.

Lastly, careful application is crucial. Content creator utilization results in Study 3 also indicate that strategies like *Make Strategic Content Transitions* and *Raise a Question* are easy to adapt, while strategies in *Add Narrative Elements* and *Precision Language Optimization* require more research and inspiration. The mixed results of knowledge recognition for some strategies (like *Add Narrative Elements*) also underscore the need for careful application and possibly further refinement of these strategies in practice.

These insights suggest that while peak strategies can indeed improve learning outcomes, their application should be thoughtful and tailored to specific learning contexts and goals. Future research could focus on optimally combining these strategies and further investigate their effectiveness across different types of content and learner populations.

6.1 Bridging Science Communication and HCI: An Interdisciplinary Approach to Online Science Video Narrative Design

This study represents a significant step in bridging the gap between Science Communication and HCI in the context of OSV narrative design. Traditionally, these fields have operated somewhat independently, with Science Communication focusing on content and messaging, while HCI has concentrated on user experience and interface design. Our research demonstrates the value of integrating these perspectives to create a more comprehensive and effective design space for OSV narrative design.

A key contribution of this interdisciplinary approach is the empirical validation of narrative strategies. While previous research in Science Communication has identified various storytelling techniques, there has been a notable lack of quantitative evidence supporting their effectiveness,

particularly in digital formats like OSVs. By applying HCI methodologies, including user studies and measurable outcomes, we've provided concrete data on the impact of specific narrative strategies on learning, engagement, and retention. This empirical approach addresses a significant gap in the literature. It moves beyond theoretical frameworks to offer evidence-based guidelines for content creators. For instance, our findings on the effectiveness of structural strategies like *Make Strategic Content Transitions* and *Enhance Introductions and Conclusions* provide actionable insights that can be immediately applied to improve OSV narrative design.

By bringing together communication studies and HCI, our research offers a unique perspective on creating engaging and effective science content in the digital age. It provides a foundation for future studies that can further explore the intersection of narrative techniques, user experience, and learning outcomes in digital science communication.

Moreover, the transferability of our narrative peak strategies extends beyond OSVs to other forms of science communication. As these strategies have the potential to make pure expository text form into more engaging format, they can be applied in transitional research to convert academic knowledge from sources such as papers, literature, and Wikipedia [98] into more accessible formats. For example, this information can be transformed into comics, cards [120], and motion graphics to make it easier for the public to understand, absorb and make use of, thus contributing to the dissemination of knowledge to the public. Beyond educational content, the design space could prove useful in various communication-intensive fields. For instance, it could aid creative writers in structuring narratives and developing characters, help journalists craft compelling news stories, and assist marketers in creating engaging advertising content. The strategies could also be valuable in public speaking, documentary filmmaking, and corporate communications, demonstrating the taxonomy's potential to enrich multiple domains of professional communication.

This broader applicability could lead to the cross-pollination of ideas between different communication domains, potentially expanding the impact of the design space beyond its original educational context and contributing to a more comprehensive understanding of effective communication strategies across various fields.

6.2 Future Directions: AI-Enhanced Narrative Strategies for OSVs

As mentioned by our participants in the workshop study, looking ahead, the integration of Artificial Intelligence (AI) into OSV creation presents exciting opportunities for enhancing narrative strategies and overall content quality. Our research lays the groundwork for AI-assisted content creation, particularly through the use of large language models (LLMs) for creating science narratives.

One promising direction is the development of AI tools that can analyze existing OSV narratives or purely educational, science-based texts and suggest improvements based on our identified peak strategies. For example, an AI system could identify sections where transitions could be enhanced or where introductions and conclusions could be strengthened. The automatic system can also provide more suggestions on modifying specific strategies by offering examples and content for creators to adopt and incorporate. This would provide content creators with valuable insights and suggestions to streamline the script optimization process.

Furthermore, the integration of visual and narrative elements in OSVs is an area ripe for AI-assisted innovation. While our current study focused primarily on textual content, future research could explore how AI can help synchronize visual elements with narrative peaks to create a more holistic and engaging viewing experience. This could involve AI-driven recommendations for visual content that complements specific narrative strategies.

The use of computational linguistics to analyze the linguistic features of peaks in OSV narratives is another exciting prospect. By leveraging natural language processing techniques, we could

identify patterns and characteristics that make certain narrative peaks particularly effective. This data could then inform more sophisticated AI models for content creation and optimization.

However, it's crucial to approach AI integration thoughtfully. While AI could become a powerful tool for content creation and optimization thereof, the human element in science communication remains irreplaceable. The goal should be to use AI as a supportive tool that enhances human creativity and expertise, rather than replacing it entirely. As we move forward, the development of AI-enhanced narrative strategies for OSVs has the potential to significantly improve engagement, memorability, production costs, and accessibility of science content. By combining insights from Science Communication, HCI, and AI, we can create more effective and engaging OSVs, ultimately contributing to better science communication across various platforms and reaching wider audiences.

6.3 Limitation

This study has several limitations that should be addressed in future research. The content analysis was limited to 10 PGC channels, potentially reducing sample diversity. Future studies should include more UGC channels for a broader view of OSV narratives and include more OSVs in our corpus to identify additional strategies to expand the design space.

Study 1 had limitations in the number of textual materials used and the separate testing of strategies across six dimensions. Future work should explore the effects of individual strategies and mixed-use strategies from different dimensions based on more diverse materials. The text modifications were primarily done by one expert, potentially introducing biases. Future research should involve multiple content creators in editing. The small sample size (16 participants) limits generalizability, and expanding it with more diverse educational backgrounds will help better assess the effects across different demographic groups.

In Study 2, input from professional science video creators was limited. Some participants noted that the initial design space required extensive reading, potentially leading to an incomplete understanding of certain strategies. Future development of an automated tool that simplifies and visualizes the strategies through videos or interactive diagrams could address this issue.

7 CONCLUSION

Our study provides a comprehensive exploration of narrative peaks and their potential to enhance memory retention and enjoyment of OSVs. By integrating theoretical insights and empirical analysis, we developed a design space to guide content creators in crafting more effective and memorable science communication narratives. The strategies identified and validated through quantitative experiments and workshop expert evaluation offer a framework for improving viewer enjoyment and cognitive retention, addressing the challenge of balancing entertainment with knowledge depth. Our findings pave the way for future innovations in automated tool development, ultimately improving the quality and effectiveness of digital science communication in the evolving landscape of online learning.

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A APPENDIX A: DEMOGRAPHIC INFORMATION OF CONTENT CREATORS

Table 3. Demographic information of content creators

Participant ID	Age	Role/Field	Experience
P1	28	PhD student (Narrative Animation)	3 months (educational videos)
P2	32	PhD student (Film)	5+ years (film industry, narrative script development)
P3	18	OSV YouTuber	5+ years (science video creation, globally renowned)
P4	29	PhD student (Film)	3+ years (film industry, narrative script development)
P5	27	Director and scriptwriter (Documentary)	3 years (informational documentaries, journalism background)
P6	28	PhD student (Education)	3 years (educational videos content creation)
P7	23	English teacher (Linguistics)	Linguistics background
P8	22	Documentary creator	Media background, international recognition

B APPENDIX B: STRATEGY USAGE IN OUR WORKSHOP

Table 4. Strategy use frequency by experts in our workshop

Level	Dimension	Peak Strategy	Frequency
Word and Sentence Level	**Precision Language Optimization**	(1) Use metaphors [43, 49]	3
		(2) Use humor	6
		(3) Use multiple transition signal words together [49, 66, 101]	**26**
		(4) Repeat key point(s) or question(s)	1
Sentence Level	**Raise a Question**	(5) Raise a question with an answer [49, 66, 73]	**13**
		(6) Raise a question without an answer	7
		(7) Inquiry and reveal [132, 135]	**17**
Sentence and Paragraph Level	**Add Narrative Elements**	(8) Add stories	7
		(9) Add real-world supporting examples [78, 82]	7
		(10) Add an imagery description [6, 49, 57]	6
Structural Level	**Enhance Introductions and Conclusions**	(11) Open with the central theme [49, 126]	**15**
		(12) Define key terminology at the beginning	6
		(13) Summarize the key knowledge at the end [94]	**12**
Structural Level	**Make Strategic Content Transitions**	(14) Shift between pros and cons	3
		(15) Bridge expository and narrative elements	4
		(16) Shift between two knowledge points	9
Any Level	**Evoke Emotional and Affective Engagement**	(17) Create quantitative emphasis [134]	7
		(18) Create negative emphasis for focused attention [49, 57, 66, 94]	2
		(19) Make positive emotion to expand action repertoire [49, 55, 57, 94, 113, 130]	6

Table 5. Details of peak strategies combined to be used in the workshop

Dimensions	Total Frequency	Strategies/Frequency					
		Strategy	Time	Strategy	Time	Strategy	Time
D2: RQ D4: IC	20	(4) RQ w an answer (11) Open with the central theme	7	(6) Inquiry and reveal (11) Open with the central theme	9	(5) RQ w\o an answer (13) Summarize the key knowledge at the end	4
D1: PL D4: CT	7	(3) Use multiple transition signal words together (11) pros and cons	2	(3) Use multiple transition signal words together (12) expository and narrative	1	(3) Use multiple transition signal words together (13) multi-perspectives	4
D3: AN	6	(8) Add stories (9) Add real-world examples	4	(8) Add stories (10) Add an imagery description	1	(9) Add real-world examples (10)Add an imagery description	1
D4: IC	6	(11) Open with the central theme (13) Summarize the key knowledge at the end	5	(12) Define key terminology at the beginning (13) Summarize the key knowledge at the end	1		

C APPENDIX C: MATERIAL MODIFICATION IN STUDY 1

In the two tables below, we presented our modification results from the OSV corpus, where the unmodified version serves as the baseline, and the modified text is used as the experimental group.

Table 6. Details of material (6 material from our OSV corpus) modification applied in Study 2. Bold text is the added peak (with the strategy used), strikethrough text is the deleted redundancy content (there may be some slight adjustments around it), and the gray text is the structural adjustment content ('remove' means to move from this place, 'put' means to put here)

Dimension	Material Modification	Dimension	Material Modification
D1: Precision Language Optimization	**I guess when you read this magic word "yawn", you are ready to yawn in a second.*(2) Use humor*** Studies have shown that yawning also increases blood pressure, stretches facial muscles and increases focus. **But why do we do this? Is it just because we are tired or sleepy? *(4)Use repetition of key terms*** When you pandiculate, you stretch all of your muscles, making them better ready to be used at any moment. So when it comes to a herd of prey animals, contagious yawning makes sense, ~~because a herd that yawns together stays alert together.~~ **like sending up a flare to alert everyone: Stay awake, stay alert! *(1) Use metaphors*** Under this theory, yawning is advantageously contagious, because that first animal to yawn acts as a sort of reminder to the rest of the herd to keep themselves ready and alert. **However, as humans, we keep this habit till now, not only for survival, but also for social connections.*(3) Use multiple transition signal words together*** Of course, when we say yawning is contagious, we don't mean like a disease. Instead, It's more about empathy. Sympathy is caring for others and wanting them to be better. Empathy is like tuning into the same broadcast, sharing others' emotions. Emotional contagion happens when the emotions around you affect how you feel, like happy people lifting your spirits or anger and fear leading to mob mentality. ~~Now,~~ Children with autism, who have difficulty with social interaction and communication, yawn less often than other children when watching videos of people yawning. **So, don't be worried If you are infected by other people's yawning. I am saying that, truly, you are a person with strong sympathy.*(3) Use multiple transition signal words together***	D2: Raise a Question	**Today, most of us want to be "cool". To be a cool person is awesome. But when we trace the history of "cool", what is "cool" exactly? Maybe the answer is the spirit of rebel.*(5) Raise a question with an immediate answer*** Our modern definition of cool may most directly come from slaves and prisoners. People in those positions are subjected to authority in a very direct way, and any kind of rebellion against authority or fighting against it is most certainly going to be answered with nothing but punishment and very little chance of success. ~~And so~~ Instead, they adopt an attitude of ironic detachment, distancing themselves from authority without direct confrontation or trouble. **But slavery and colonization are history now. What does "cool" mean in modern life? Can we find something beyond a unique lifestyle? *(7) Inquiry and reveal, (6) Raise a question without an answer*** Now, later on in the 1940s, the actual word cool began to stick to this attitude. it came out of the smoke-filled nightclubs where jazz, beatnik, and bohemian culture thrived. The only way to freshen up that smoke-filled air was to open windows and let the cool night air in. Saxophonist Lester Young is credited with making this connection and popularizing the use of the word cool, even cooler is the fact that Lester also popularized the use of the word bread to mean money. Well look at that, the sun has come out. That's cool. ~~It also means that it's a good time to talk about the brain.~~ **It also means the attitude. So, are we cool of understanding "cool"?*(6) Raise a question without an answer***

Table 7. Details of material (6 material from our OSV corpus) modification applied in Study 2. Bold text is the added peak (with the strategy used), strikethrough text is the deleted redundancy content (there may be some slight adjustments around it), and the gray text is the structural adjustment content ('remove' means to move from this place, 'put' means to put here)

Dimension	Material Modification
D3: Add Narrative Elements	We know which species of mosquito are vectors, or carriers, of the worst viruses and parasites that can infect humans. Researchers are targeting these species, developing ways to kill them or to kill the dangerous stuff inside them. Take the genus Aedes, which transmits lots of awful diseases. One particularly nasty species is Aedes aegypti, which is the primary vector for the Yellow Fever, Dengue, Chikungunya, and Zika viruses. A. aegypti is not just a pest, it's one of the most medically significant pests. (remove: So it's the focus of lots of recent experiments in targeted mosquito eradication.) **In 1970, hundreds of yellow fever cases from Aedes aegypti mosquitoes were reported in Kinshasa, Zaire, and nearby areas. The outbreak was eventually controlled after several months.** ***(8) Add stories*** However, ~~But~~some of the most promising research doesn't set out to kill mosquitoes outright. **How difficult to eradicate mosquitoes using human effort? Methods like hunting them, using electric swatters, or spraying chemicals. All these methods are too demanding and also have adverse effects on humans.*****(9) Add real-world supporting examples*** (put: Instead, scientists figured out how to genetically modifies them.) In 2015, a British company called Oxitec created male A. aegypti mosquitoes with a self-limiting gene, which basically means that the gene can stop their cells from functioning normally. When these genetically modified mosquitoes are released and mate with females in the wild, the self-limiting gene gets passed on to their offspring. Those offspring usually can't develop properly and die before they become adults. No adult mosquitoes means no disease transmission.
D4: Enhance Introductions and Conclusions	**There is a magical experience where you feel like you've been through something before, even though you know you haven't. This feeling is so common that it has been given a special term: "deja vu." Deja vu is a frequent experience that has puzzled scientists and researchers for decades.*****(10) Summarize the key knowledge at the end, (12) Define key terminology at the beginning*** Our various sensory inputs, such as smells, sounds, and sights, are normally processed and mixed together as one event. ~~Another déjà vu theory says,~~ However, if one of those stimuli is recorded out of sync, the late-arriving information could be flagged as a different event, which makes it feel as if it's happened before. Another theory proposes that déjà vu could be a malfunction in how memories are made in the first place. Normally, new experiences stop off in our short-term memory before being written into long-term storage. If we skip the first step, it could feel like we're recalling new events as old ones. Perhaps when we focus on one part of our environment, the rest of our world drifts to the unconscious, and when we snap back to reality, it feels like we've been there before, because we have, just now. These feelings of misplaced familiarity are familiar to us, but the what, the where, and the why of déjà vu remains unknown. ~~There's no neat answer, but no mind or memory is perfect.~~ **There are dozens of plausible explanations for it, and maybe more than one is right. The only way we'll get to the bottom of déjà vu is to experience it all over again.*****(13) Summarize the key knowledge at the end***

Table 8. Details of material (6 material from our OSV corpus) modification applied in Study 2. Bold text is the added peak (with the strategy used), strikethrough text is the deleted redundancy content (there may be some slight adjustments around it), and the gray text is the structural adjustment content ('remove' means to move from this place, 'put' means to put here)

Dimension	Material Modification
D5: Make Strategic Content Transitions	Unless you were alive in the 1960s, every banana you have ever eaten was pretty much genetically identical, this is a Cavendish, but it wasn't always our banana of choice. Until the 1960s, everyone was eating the same banana, it was just a different banana—the Gros Michel, a bigger, sweeter fruit with thicker skin. **It was said to taste far better than the Cavendish bananas of today. What led us away from the Gros Michel is a sad history.** ***(16)Shift between multi-perspectives*** A fungicide-resistant pathogen called Panama disease began infecting Gros Michel crops. The genetic monotony of the Gros Michel crop was its undoing. By the time growers understood how vulnerable their crops were, the Gros Michel variety was all but extinct. The entire banana industry had to be retooled for the Cavendish. Since they're seedless, the only way to reproduce them is to transplant part of the plant stem. For the last 50 years, we've been good with the Cavendish because it's more resistant to Panama disease. **Should we be reassured? The answer, of course, is no. A single gene makes the Cavendish species vulnerable to being wiped out by a new pathogen.*****((14) Comparative transition between pros and cons)*** ~~However, somewhat terrifyingly,~~ (remove: a strain of Panama disease that affects the Cavendish strain that we all eat has been identified.) The fungus only has to figure out how to infect and destroy a single individual, and suddenly there's no diversity to stop it, or even slow it down. (put: Now, a new strain of Panama disease targets the Cavendish banana,) ~~That's led to a lot of scientists worrying about~~ leading scientists to worry about its potential extinction.
D6: Evoke Emotional and Affective Engagement	This year saw one of the worst droughts in history, one of the hottest years on record, and a heat wave in December, all of which exacerbated the conditions across the country. But as the fires have rapidly spread, they now pose an even greater danger. (put: As of early January 2020,) **25 people have died (remove: have died as of early January 2020), thousands of homes have been destroyed, tens of thousands of homes have been without power, and 14.7 million acres of land have been burned. That's nearly seven times the amount that was burned during the Amazon rainforest fires of 2019. Or, put another way, it's about twice the size of Belgium!*****(17) Create quantitative emphasis*** **The contrast between Australia's calm wilderness and the raging fires is stark. One moment, it's a serene haven for wildlife; the next, it is an unrecognizable wasteland.*****(18) Create negative emphasis for focused attention)*** ~~And this is what has led ecologists to estimate that~~ This devastation has led ecologists to estimate that around 500 million animals have died in the fires. ~~So as of editing this video,~~ (remove: scientists have now estimated that around 1 billion animals have died)Now, (put: scientists estimate the number has reached 1 billion,) including 8,000 koalas. While some early reports suggested that the fires could make koalas functionally extinct, experts don't believe this to be true. However, it has been estimated that around 1/3 of the koalas in New South Wales have been killed, based on how much of their habitat has burned. **Image of a lone, singed koala wanders through the charred remains of a lush forest. This heartbreaking image highlights the severe impact of the fires and the urgent need for action.*****(18) Create negative emphasis for focused attention), (19) Make positive emotion to expand action repertoire)***

Author Statement Regarding Prior Publications and Submissions

This submission to *ACM Transactions on Computer-Human Interaction (TOCHI)* has no relation to the authors' previous publications or any concurrently submitted papers. The research presented in this manuscript is entirely original, offering new findings and contributions that have not been explored in the authors' prior works.

It is not connected to any ongoing or completed research projects previously conducted by the authors. This paper is a new submission and has never received any reviews or feedback.

The submission is not currently submitted elsewhere and recently submitted to a conference.