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# Sustainable Storytelling in Digital Climate Campaigns: A Comparative Analysis of Visual Communication Strategies

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***Abstract***. *Climate change requires urgent and strategic communication efforts to inspire public awareness and behavioral change. This study investigates the comparative effectiveness of three visual storytelling strategies, data visualization, interactive infographics, and narrative illustration, on digital platforms in shaping public comprehension, emotional response, and behavioral intention regarding climate change. A pretest-posttest control group experiment was conducted involving 120 participants aged 18–35, randomly divided into four groups. Each experimental group was exposed to one of the three visual strategies, while the control group received text-based narratives. Measurement instruments included a 10-item comprehension test, the Positive and Negative Affect Schedule (PANAS), and a behavioral intention scale. Statistical analysis using one-way ANOVA and Tukey's post-hoc test revealed significant differences ($p < 0.01$) among the groups. Interactive infographics consistently produced the highest gains in comprehension (+3.1), positive emotional response (+2.7), and behavioral intention (+3.4), followed by narrative illustrations. Data visualizations were most effective for cognitive understanding but less emotionally engaging. The findings support the Elaboration Likelihood Model by highlighting how different visual modalities engage both rational and affective pathways. This study contributes theoretically to affective computing and practically to climate communication design by recommending visual strategies tailored to maximize public engagement and sustainability impact. Future studies are encouraged to explore longitudinal effects and cultural contexts in environmental storytelling.*

***Keywords:*** *Visual Storytelling, Climate Change Communication, Interactive Infographics, Emotional Engagement, Sustainable Digital Campaigns*

## INTRODUCTION

Climate change is a global crisis that threatens ecosystems, public health, and socio-economic sustainability. According to (McKay et al., 2022), global temperatures have already risen by approximately 1.1°C compared to pre-industrial levels and are likely to surpass the 1.5°C threshold without strong mitigation efforts. In light of this, effective public communication becomes imperative to raise awareness and foster collective action. The rapid advancement of digital technology has positioned social media platforms, interactive websites, and campaign-based applications as key channels for disseminating climate-related messages (Vu et al., 2021).

Visual communication plays a crucial role in transforming complex scientific information into accessible, emotionally resonant messages that encourage audience engagement (Q. Chen et al., 2024). Strategies such as data visualizations, interactive infographics, and narrative illustrations have been recognized as impactful tools for improving environmental literacy and promoting behavioral change (Bhat & Alyahya, 2024). Despite their growing use, existing literature tends to focus on the general effectiveness of visual media or aesthetic appeal, without systematically comparing different visual approaches in terms of their cognitive, affective, and conative impact (Eberhard & Eberhard, 2021). This gap highlights the need for empirical studies

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that evaluate not only whether visual storytelling is effective, but also which types of visual strategies are most impactful.

Few studies have quantitatively examined the comparative performance of multiple visual modalities in a controlled setting. While (Ma & Yang, 2022) suggested that narrative visuals foster emotional connection, and (Freistein & Gadinger, 2022) Although it emphasized the persuasive power of visual narratives in political discourse, there remains a lack of systematic comparison across data-driven, interactive, and emotive formats. In particular, there is little research exploring how different types of AI-supported or designer-generated visual media influence audience understanding, emotional response, and behavioral intention regarding climate change. To address this research gap, this study aims to compare the effectiveness of three prominent visual communication strategies, data visualization, interactive infographics, and narrative illustration, using a pretest-posttest control group design.

By evaluating changes in comprehension, emotional affect, and behavioral intention, this study seeks to identify which visual modality offers the most holistic impact in digital environmental communication. This inquiry is guided by key research questions concerning which visual strategy most effectively enhances understanding of climate issues, how different visual formats influence emotional response and behavioral intent, and to what extent visual approaches outperform text-based narratives in digital campaigns. This research contributes theoretically by reinforcing the Elaboration Likelihood Model (ELM) as a framework for understanding message processing pathways, and practically by offering data-driven insights for designers, environmental communicators, and policymakers. Ultimately, this study positions visual storytelling not merely as a means of aesthetic expression but as a strategic instrument in the design of sustainable digital interventions for climate action.

## LITERATURE REVIEW

### *A. Visual Communication in Climate Change Discourse*

Climate change is a complex and multidimensional global issue that demands communication approaches capable of reaching diverse segments of society (Purhita & Rudjiono, 2024). Within this context, visual communication plays a central role in effectively conveying environmental messages. Visuals simplify the complexity of scientific data into representations that are easily understood and capable of evoking emotions that drive behavioral change (Abos et al., 2024). Therefore, visuals are not merely supplementary to information, but function as strategic instruments in constructing sustainability narratives. With the advancement of digital

technology, social media and other online platforms have emerged as primary channels for environmental campaigns.

These channels enable the rapid, wide-reaching, and interactive dissemination of messages. In this context, visual communication functions not only as a medium for delivering information but also as a tool for persuasion and public engagement. (Boscarino, 2022) argues that visual messages presented in narrative form possess a greater capacity to shape public opinion than purely text-based narratives. Evocative visual representations, particularly those structured as stories, can activate affective dimensions and foster deeper understanding of the impacts of climate change. (Zeng et al., 2023) further emphasize that visualizations depicting human figures or direct impacts on local communities can heighten risk perception and strengthen individuals' intentions to engage in environmental action.

### *B. Visual Strategies: Data Visualization, Interactive Infographics, and Narrative Illustration*

In the context of digital climate change campaigns, three commonly employed visual approaches include data visualization, interactive infographics, and narrative illustration. Each possesses distinct strengths in influencing audience perception and behavior. Data visualization is typically used to depict trends, causal relationships, and science-based future projections. Through the use of charts, maps, or diagrams, quantitative data is presented in formats that are both informative and visually engaging, as described by (Wadoux et al., 2022). This strategy is particularly effective in enhancing scientific literacy and reinforcing evidence-based arguments.

Interactive infographics offer a more immersive user experience by enabling active participation in the exploration of information (Prihatmoko & Setiyadi, 2024). Through features such as click, drag, or animation, audiences can navigate data independently and within a contextual framework. (Getenet & Tualaulelei, 2023) emphasize that interactivity can extend attention span, enhance cognitive engagement, and strengthen information retention. In contrast, narrative illustration focuses on an emotional approach through visuals that are symbolic and personal. This method connects climate change issues with cultural values, local identities, and everyday experiences, as discussed by (Castro & Sen, 2022).

This strategy is effective in bridging the psychological distance from global issues, particularly for audiences who perceive themselves as removed from the direct impacts of climate change. However, to date, few studies have systematically compared the effectiveness of these three visual strategies within a single, comprehensive research framework. Previous studies have tended to evaluate one type of visual medium in isolation, without examining its effects on

cognitive, affective, and conative variables within a controlled experimental setting (T. Chen et al., 2024).

### *C. Research Gap and Study Urgency*

Although visual communication has been widely recognized as a key strategy in conveying climate change issues, scholarly research in this field still faces several gaps. Previous studies have tended to adopt qualitative or descriptive approaches, often focusing on aesthetic aspects without providing quantitative evaluations of audience perception and behavior (Shin, 2022). This has led to limitations in generating empirical evidence that can inform the design of effective communication campaigns. Moreover, psychological dimensions such as risk perception, empathy, and behavioral intention are rarely integrated into visual communication studies, despite their significant influence on communication effectiveness.

Furthermore, there is currently no integrated comparative model that systematically evaluates various visual strategies, such as data visualization, interactive infographics, and narrative illustration, within the context of digital climate change campaigns. Previous studies have tended to be fragmented, focusing solely on a single type of medium without assessing the relative strengths of different approaches (Terren & Borge, 2021). Therefore, this study adopts a quantitative experimental approach using a pretest-posttest control group design to measure the impact of these three strategies on audience comprehension, emotional engagement, and behavioral intention. The findings are expected to offer both theoretical and practical contributions for stakeholders seeking to design environmental communication that is more inclusive, evidence-based, and transformative.

## METHODS

### *A. Research Design*

This study employed a quantitative experimental design using a pretest-posttest control group structure to assess the effects of three visual storytelling strategies, data visualization, interactive infographics, and narrative illustration, on participants' comprehension, emotional response, and behavioral intention toward climate change. A fourth group served as a control and was presented only with a text-based narrative that contained the same core message content as the visual interventions. This design allowed for a systematic comparison across different formats and enabled the researchers to measure changes in the participants' responses after exposure to the materials. The experimental structure was chosen to enhance internal validity and provide reliable insights into the impact of visual communication on climate-related attitudes.

A total of 120 participants aged 18 to 35 were recruited using purposive sampling, targeting individuals who are active users of digital platforms such as Instagram and Twitter. This demographic was selected due to its high exposure to online visual content and relevance to digital environmental campaigns. All participants were randomly and evenly assigned to one of four groups, each consisting of 30 individuals, to ensure a balanced distribution and to minimize potential bias. Random assignment also helped maintain equivalence in baseline characteristics across the groups, supporting the validity of the statistical comparisons performed in the study.

*B. Materials and Instruments*

Each experimental group was exposed to a different type of visual material, all of which were developed around consistent climate-related themes, including rising global temperatures, sea-level rise, and biodiversity loss. The data visualization group received static visuals such as charts, bar graphs, and geographic climate maps that conveyed scientific information quantitatively. The interactive infographic group was provided with dynamic content featuring scrollable sections, clickable icons, and animated transitions to promote user engagement and self-guided exploration. Meanwhile, the narrative illustration group viewed sequential comic-style visuals depicting relatable stories of individuals affected by climate change, designed to evoke empathy through personal and cultural contexts. To ensure content consistency and relevance, all visual materials were reviewed and validated by experts in environmental communication and visual design.

To measure the study's outcome variables, three validated instruments were used. First, a 10-item multiple-choice test based on IPCC literacy standards was used to assess participants' cognitive comprehension of climate issues. Second, emotional responses were measured using the Positive and Negative Affect Schedule (PANAS), which captured self-reported affective states before and after exposure. Third, a 7-item Likert scale was used to evaluate participants' behavioral intention toward pro-environmental actions such as recycling, reducing carbon emissions, and advocacy participation. These instruments were pre-tested in a small pilot study to confirm clarity and internal consistency, with all reliability coefficients exceeding a Cronbach's alpha of 0.8. Emotional assessments were conducted solely through participant self-reports, with no use of AI-based emotion detection or external human annotation, to preserve the authenticity and subjectivity of individual affective responses.

*C. Procedure: From Exposure to Insight*

The experimental procedure was carried out over a period of three weeks using a secure and accessible online platform. During the first week, all participants were asked to complete a

pretest that measured their baseline levels of comprehension, emotional response, and behavioral intention regarding climate change. In the second week, participants received their assigned intervention materials—either data visualizations, interactive infographics, narrative illustrations, or text-based narratives—and were instructed to view them asynchronously within a specific time frame. Digital engagement metrics such as time-on-page, click activity, and scrolling behavior were tracked to ensure adequate exposure to the stimuli. All participants provided informed consent prior to their involvement, and ethical approval was obtained to safeguard participant privacy and data integrity.

Data analysis was conducted using SPSS and JASP software to ensure accuracy and reproducibility of statistical results. Prior to hypothesis testing, normality was assessed using the Kolmogorov–Smirnov test, while homogeneity of variance was verified with Levene's test; both confirmed that parametric assumptions were satisfied ($p > 0.05$). A one-way ANOVA was performed to evaluate whether significant differences existed among the four groups on each of the three dependent variables: comprehension, emotional affect, and behavioral intention. When ANOVA results indicated statistical significance, Tukey's HSD post-hoc test was employed to identify specific group differences. To complement these results, Cohen's d was calculated to measure the effect size, and the difference between pretest and posttest scores was analyzed to assess the magnitude of change within each group.

### *D. Data Analysis Techniques*

The collected data were analyzed using SPSS and JASP software to ensure the accuracy of statistical computations. Before conducting the main tests, the data were first assessed for normality using the Kolmogorov–Smirnov test and for homogeneity of variances using Levene's Test, to confirm that the fundamental assumptions of analysis of variance were met. Subsequently, a one-way ANOVA was performed to identify mean differences among the treatment groups. If significant differences were found, a Tukey post-hoc test was conducted to determine which specific group pairs differed significantly. This step is crucial for statistically determining the relative effectiveness of each visual communication strategy.

In addition to significance testing, the analysis also includes the calculation of effect size using Cohen's d to assess the strength of the influence between groups. This measurement is complemented by an analysis of the difference between pretest and posttest scores to determine the extent of change resulting from the intervention. The formulas used in the analysis are explained as follows. The F-ratio used in the ANOVA test is presented in Formula (1). The calculation of effect size using Cohen's d is shown in Formula (2). Meanwhile, the difference between posttest and pretest scores is represented in Formula (3).

**Formula 1. ANOVA Test**

$$F = \frac{MS_{between}}{MS_{within}} \quad (1)$$

**Formula 2. Effect Size (Cohen's d)**

$$d = \frac{M_1 - M_2}{SD_{pooled}} \; dengan \; SD_{pooled} = \sqrt{\frac{(SD_1^2 + SD_2^2)}{2}} \quad (2)$$

**Formula 3. Change in Score Difference**

$$\Delta X = X_{posttest} - X_{pretest} \quad (3)$$

Through this approach, the analysis not only determines whether the differences between groups are statistically significant, but also evaluates the magnitude of the treatment's impact. This comprehensive quantitative interpretation provides a robust foundation for the conclusions and recommendations drawn from the study.

*E. Participant Distribution*

The participants in this study were evenly distributed into four groups, each consisting of 30 individuals. The three experimental groups were exposed to different types of visual materials, data visualization, interactive infographics, and narrative illustrations, while the control group received only text-based narratives. Participants were randomly assigned to each group following an initial screening based on inclusion criteria: individuals aged 18–35 who were active social media users. This approach ensured baseline homogeneity and minimized systematic bias that could affect measurement outcomes. With an equal number of participants in each group, the study maintained sufficient statistical power to examine differences across treatment conditions.

A proportional distribution enabled the researchers to perform equitable comparisons across cognitive, affective, and conative variables. Each visual strategy was tested against the control group to assess the extent to which the presence of visual elements influenced audience perception and behavioral intention. Moreover, the relatively large and evenly distributed number of participants enhanced the external validity of the findings, allowing for greater generalizability to broader digital populations. Table 1 presents a detailed breakdown of participant allocation based on the type of visual media received.

**Table 1. Participant Distribution by Visual Strategy**

| Group | Type of Visual Media | Number of Respondents |
|---|---|---|
| Group 1 | Data Visualization | 30 |
| Group 2 | Interactive Infographics | 30 |
| Group 3 | Narrative Illustrations | 30 |
| Control Group | Text-Based Narrative | 30 |

**RESULTS**

### *A. Statistical Analysis*

The results of the statistical analysis confirmed that the data met the assumptions required for parametric testing. One-way ANOVA revealed significant differences among the four groups in all three measured variables. Specifically, there were statistically significant effects for comprehension ($F(3,116) = 18.29$, $p < 0.001$), positive emotional response ($F(3,116) = 22.65$, $p < 0.001$), and behavioral intention ($F(3,116) = 25.94$, $p < 0.001$). These findings indicate that the type of visual strategy used had a meaningful impact on participants' cognitive, affective, and conative outcomes.

Further analysis using Tukey's HSD post-hoc test showed that the group exposed to interactive infographics significantly outperformed all other groups across the three domains ($p < 0.01$). The narrative illustration group also produced significantly higher scores in emotional engagement and behavioral intention when compared to the control group. However, its impact on comprehension was less pronounced than that of data visualizations and infographics. These results suggest that while each visual strategy has strengths, interactive infographics offer the most comprehensive benefits in communicating climate-related messages effectively.

### *B. Pretest–Posttest Score Changes*

To assess the effectiveness of each visual storytelling strategy, changes in participant scores between the pretest and posttest were analyzed across three key variables: comprehension, emotional response, and behavioral intention. These variables reflect cognitive, affective, and conative dimensions of engagement with climate-related content. The score differences help indicate how much impact each intervention had on the participants. The detailed results of these score changes are summarized in Table 2.

**Table 2. Pretest–Posttest Score Gains by Group**

| Group | Comprehension (Δ) | Positive Emotion (Δ) | Behavioral Intention (Δ) |
|---|---|---|---|
| Data Visualization | +2.4 | +1.8 | +2.1 |
| Interactive Infographic | +3.1 | +2.7 | +3.4 |
| Narrative Illustration | +2.0 | +3.0 | +2.9 |
| Text (Control) | +0.9 | +0.4 | +0.7 |

As shown in the table, the interactive infographic group experienced the highest gains across all three variables, with particularly strong results in behavioral intention and comprehension. Narrative illustrations showed a notable increase in emotional engagement, outperforming even the infographic group in that domain, although they were slightly less effective in improving factual understanding. The data visualization group performed best in terms of comprehension after infographics, but its influence on emotional and behavioral

outcomes was more limited. In contrast, the control group, which received only text-based information, showed minimal improvement in all three areas.

These results suggest that while all visual strategies are more effective than text alone, each format offers different strengths depending on the desired communication outcome. Interactive infographics appear to provide the most balanced impact by combining clarity, interactivity, and narrative appeal. Narrative illustrations are particularly effective when the goal is to foster empathy and emotional connection. Meanwhile, data visualizations may be best suited for enhancing scientific comprehension but may require supplementary elements to drive action. Overall, visual storytelling enhances the persuasive power of climate communication by addressing both rational and emotional dimensions of audience engagement.

### *C. Evaluation of Findings*

The results of this study support the hypothesis that visual approaches have a significant influence on the formation of perceptions and behavioral intentions concerning climate change issues. The interactive infographic strategy proved to be the most effective, as it successfully integrates both logical and emotional appeals simultaneously, thereby enhancing the message processing experience. This aligns with the findings of (Meuschke et al., 2022), who assert that visual interactivity can prolong audience engagement and improve information retention. The data visualization approach demonstrated superiority in enhancing cognitive understanding, as it facilitates the central processing route within the framework of the Elaboration Likelihood Model (Shahab et al., 2021). In contrast, narrative illustrations predominantly activate the peripheral route, which operates through affective triggers and personal experiences.

The consistency of these findings with prior research underscores the importance of visual communication as a strategic instrument in fostering empathy and public engagement. (Mostajeran et al., 2021) demonstrated that visual representations depicting direct impacts on individuals or local communities can heighten perceptions of environmental risk. Similarly, (León et al., 2022) emphasized that visual messages are capable of overcoming psychological barriers to complex global issues such as climate change. This study not only confirms the relevance of those findings within the digital context but also extends them through a quantitative and comparative approach. Accordingly, the use of appropriate visual strategies can serve as a transformative tool in sustainability communication.

From a practical standpoint, these findings indicate that well-targeted visual campaign design can significantly enhance the effectiveness of climate communication. The selection of visual strategies that align with the context and audience characteristics is crucial, particularly in

an era saturated with digital information. Interactive infographics, which emphasize active engagement, have proven to be more effective in reaching digital-native audiences who favor dynamic and participatory visual content. This finding aligns with the study by (Gandee et al., 2024), which observed that younger generations are more responsive to environmental messages that are visually rich and interactive. Therefore, this research offers a concrete contribution to the practice of environmental communication grounded in design and technology.

## DISCUSSION

The findings of this study demonstrate that different visual storytelling strategies produce distinct effects on how audiences process, feel about, and respond to climate change messages. Among the three strategies tested, interactive infographics emerged as the most effective in generating improvements across comprehension, emotional response, and behavioral intention. This outcome suggests that combining data, visual engagement, and interactivity facilitates both rational and emotional processing, thus aligning with the core tenets of the Elaboration Likelihood Model (Teeny et al., 2021). According to this model, persuasive communication is most effective when it engages both the central (cognitive) and peripheral (emotional) routes of information processing. The consistent performance of interactive infographics across all outcome measures underscores their capacity to activate this dual-route engagement in digital environmental communication.

In comparison, the data visualization strategy was particularly successful in enhancing comprehension but was less effective in eliciting strong emotional responses or motivating behavioral intention. This suggests that while analytical graphics are useful for conveying complex climate data, they may not be sufficient to trigger deeper affective or behavioral outcomes. On the other hand, narrative illustrations, while not as strong in promoting cognitive understanding, proved powerful in fostering empathy and encouraging action, likely due to their story-driven format and personal relevance. These results highlight that the persuasive and educational power of visual content depends not only on its factual accuracy but also on how the content is structured and emotionally framed. The study reinforces the idea that form and format matter, and that the design of visual communication should be strategically aligned with the specific goals of climate campaigns.

This study provides significant theoretical contributions by extending the Elaboration Likelihood Model (ELM) into the domain of environmental visual storytelling. Empirical evidence, it demonstrates how different design modalities, ranging from data visualizations to narrative illustrations, activate distinct cognitive and affective pathways in the audience. This dual-channel activation confirms the applicability of ELM beyond verbal and textual messages,

emphasizing that visual media can also engage both central (rational) and peripheral (emotional) routes of persuasion. The findings thus enrich our understanding of how design formats function not only as conveyors of information but also as tools of psychological influence in sustainability communication.

Moreover, the study introduces a comparative framework that future researchers can adopt in the fields of affective computing, visual persuasion, and sustainable communication. By quantifying the differential impacts of various visual strategies, it lays the groundwork for more targeted investigations into how form and function interact in persuasive design. The results also offer valuable insights into optimizing visual storytelling for emotional salience, not just clarity, an important consideration in the context of AI-generated and generative art platforms. As visual media become increasingly algorithm-driven, this research underscores the need for emotionally intelligent design principles that go beyond aesthetics to address audience perception, empathy, and behavioral motivation.

The findings of this study offer practical insights for various stakeholders involved in climate communication, particularly designers, campaign strategists, and platform developers. For designers, incorporating narrative and interactive elements into visual content can significantly enhance message engagement by appealing to both the cognitive and emotional dimensions of the audience. Sustainability campaigns should therefore move beyond static infographics and adopt formats that encourage user interaction and emotional connection. Non-governmental organizations (NGOs) and climate communicators should strategically align their visual choices with specific campaign goals—using data visualizations for comprehension, narrative illustrations for empathy, and interactive infographics for motivating action.

For digital platform developers and UX designers, the study suggests that interface design can be optimized to support personalized, emotionally engaging experiences. These insights are especially valuable for applications that aim to educate users or mobilize public action on environmental issues. Additionally, the research draws attention to the ethical responsibilities associated with visual design, particularly when emotionally persuasive content may risk oversimplifying data or contributing to climate misinformation. Designers and developers must balance emotional appeal with informational accuracy to ensure that persuasive visuals remain both effective and trustworthy. As visual storytelling continues to evolve in the digital space, this study underscores the importance of intentional, audience-aware design strategies in shaping public engagement with sustainability.

The findings of this study are consistent with those of (Mrkva et al., 2021), who demonstrated that attention-capturing features in visual design significantly increase perceived

urgency and risk awareness in environmental contexts. This study also builds upon the work of (Duan & Bombara, 2022), who emphasized the importance of emotional valence and visual framing in reducing psychological distance and promoting climate engagement. By empirically testing emotional and cognitive responses to multiple visual formats, the present study confirms that emotional appeal—when combined with appropriate design structures—can enhance both understanding and action. These results validate and extend prior insights into the role of visual affect in sustainability communication.

However, this research advances the discourse by introducing a comparative experimental framework that systematically evaluates the strengths and limitations of three distinct visual strategies. Unlike previous studies that often examined single formats in isolation, this study demonstrates that no single visual style universally addresses all communication goals. For example, data visualizations may aid comprehension but fall short in emotional resonance, while narrative illustrations do the opposite. By adopting a controlled, multi-variable experimental design, this study provides stronger empirical grounding for determining how specific design choices influence audience outcomes—particularly in fast-paced, mobile-first digital environments where visual storytelling dominates public discourse.

## CONCLUSION

This study concludes that visual storytelling plays a crucial role in enhancing public comprehension, emotional engagement, and behavioral intention within the context of climate change communication. Through a controlled experimental comparison of data visualizations, interactive infographics, and narrative illustrations, the research provides strong empirical evidence of the varied effectiveness of each strategy. Among the three, interactive infographics proved to be the most impactful, demonstrating consistent gains across cognitive, emotional, and behavioral dimensions. While data visualizations supported scientific understanding most effectively, narrative illustrations stood out in fostering empathy and emotional resonance. These differentiated outcomes highlight that the choice of visual format should align closely with the specific objectives of a campaign.

The findings reinforce the relevance of the Elaboration Likelihood Model, emphasizing the importance of combining rational and emotional messaging routes to drive meaningful audience responses. In practice, these results offer valuable guidance for designers, communicators, and digital strategists in selecting and tailoring visual tools for public engagement. The study also contributes to broader academic conversations in affective computing and computational aesthetics, positioning visual strategies as mechanisms that can simultaneously inform and inspire. Future research should consider longitudinal designs to examine sustained effects over

time, while also broadening participant demographics to increase applicability. Additionally, integrating emerging technologies—such as AI, augmented reality, and adaptive storytelling—may enhance personalization and cultural relevance, helping to translate complex scientific messages into compelling public narratives.

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