Exploring and Explaining Climate Change: Exploranation as a Visualization Pedagogy for Societal Action

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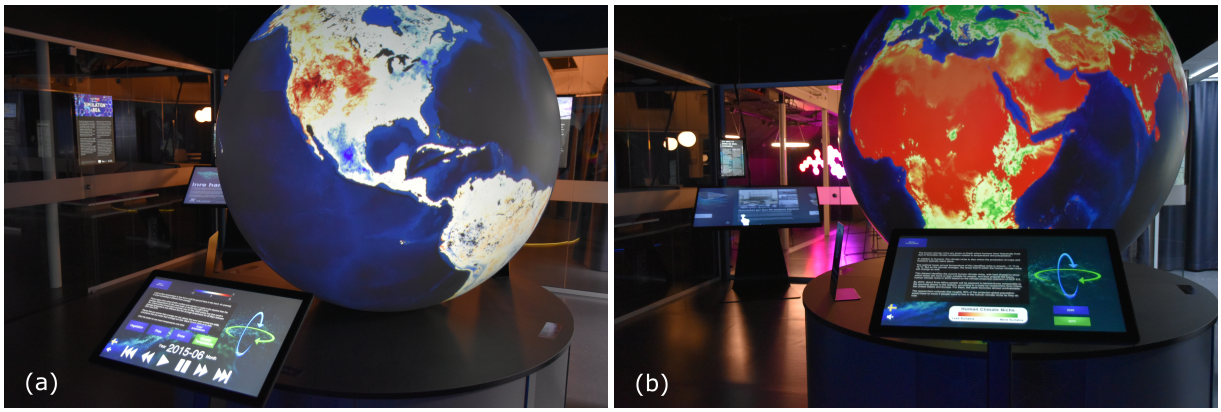

Figure 1: The Globe exhibit offers a 360° view of the planet with different datasets and models being rendered on the spherical surface. (a) depicts a user-controlled animation showing the evolution of ground temperature anomalies over time when compared to the same week or month from 2001-2010; (b) displays predicted habitable and inhabitable locations on the planet in 2070, where a large proportion of Africa and south-east Asia is likely to be inhabitable.

Abstract

Engaging mass audiences with crucial societal issues, such as climate change, can be provided through interactive exhibits designed around the paradigm of exploranation. We present example interactive installations in the newly founded Wadströms Exploranation Laboratory that explain various aspects of climate change while allowing public participants to explore the real scientific data. We describe how effects and causes of climate change can be communicated by two of the installations that allow for interactive opportunities to explore the underlying data while gaining insight into climate change sources and effects. We close with implications for future work on exploranation as an emerging visualization pedagogy in public spaces.

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1 Introduction

For decades scientists have been warning policy makers and the public about the imminent dangers of climate change. Climate change is often considered a very unique challenge in science communication as it combines a very abstract and complex problem that often triggers psychological defense mechanisms [12]. Awareness of climate change has increased in particular due to activists such as Greta Thunberg and the death of the Okjökull glacier. While the overall awareness of the immediacy of the climate crisis has undoubtedly risen [19], many people still do not consider it an existential crisis, with significant implications for themselves and their society. The behavioral responses to the crisis are still far from the urgency that is needed to catalyze more action [17].

The relatively low emotional involvement in the climate crisis is particularly problematic as emotional responses to the climate are good predictors of climate actions [19]. Whether through exercising political pressure or by directly changing lifestyle [20], the general public can directly participate in political or personal actions that would help mitigate climate change. It is thus necessary to better foster and leverage a meaningful emotional connection to the climate crisis such that citizens feel concerned enough to act. As such, effective communication about climate change becomes crucial as it

can help activate public emotional engagement. One intervention in this regard is to expose the general public to visualizations that communicate and model real scientific climate data, and allow citizens to engage and interact with these media as a means to reflect on climate phenomena [18]. While formal settings such as schools are important avenues to explain and foster knowledge about the climate crisis, traditional classroom activities might not always provide powerful tools for gaining access to the complex mechanisms underpinning climate change [9]. Contemporary classroom activities might not always spark enough interest or induce emotions to take personal responsibility for one's actions [17].

In this context, the role of non-traditional and "out-of-school" learning contexts such as science centers and museums play a particularly important role. These public spaces are crucial for enticing new learning experiences and interest for the general public [14] as well as promoting science to communities that might not have resources, a sense of inclusion, or direct access to scientific developments [2]. Therefore, science centers play a pinnacle role in communicating and explaining climate change to induce action in the general public.

Based on the paradigm of exploranation, this paper presents two examples of interactive installations that contribute to pedagogical visualization for communicating climate change. Engaging with these installations provides new explorative and explanative opportunities to gain awareness and knowledge about climate change. We describe the development of these interactive visualizations in light of their potential as communicative and pedagogical tools for societal action.

2 Exploranation for visualization pedagogy

Ynnerman et al. [6, 21] have coined the term "exploranation" to describe the emerging convergence of domain expert exploratory visualization tools used to make sense of data with explanatory visualization tools that aim to communicate scientific concepts to the general public. The primary and novel premise of exploranative exhibits is that the public can explore the same visualized datasets or models used by experts, and at the same time arouse their curiosity and interest. To date, only a handful of interactive visualization systems have embedded this synergy for public science communication. To facilitate this exploration, visitors are provided with annotations, figures, or other forms of explanations that assist their sense-making of the complex data. One of the key features of exploranation is to make real scientific datasets and models accessible to the public.

Exploranative exhibits provide a meaningful pedagogical opportunity for accessing and interacting with challenging scientific concepts that are often beyond our everyday perception. Directly exploring real visualized scientific data allows for self-generated explanations of the communicated concepts. Thus, actively forging interconnections between interacting with the real visualized data and simultaneously constructing an understanding of an abstract scientific phenomenon, is where the pedgagogical power of exploranation resides [6]. The design and implementation of exploranative installations for learning requires meaningful integration of afforded interactivity, data visualization and intended scientific communication [6]. Harnessing visitor engagement with exploranative exhibits can be considered in terms of at at least three situations, namely i) free interaction, ii) guided interaction, or iii) advanced engagement that might involve a visitor transforming their exploration into their own unique content output [1]. We argue that exploranative-based exhibits in science centers (see [22]) can provide visitors opportunities for accessing and confronting challenging climate-change concepts, and in turn, engender potential behavioural shifts.

Few studies have focused on the impact and role that interaction with real scientific data can bring to the communication and understanding of abstract science concepts [11, 13]. Consequently, and considering the previously highlighted potential of interactive experiences to foster a better understanding of climate change [3], exploranative exhibits provide compelling opportunities to communicate the climate crisis.

3 Exploranation for Climate Communication

In tackling specific societal challenges for which interactive visualizations could be helpful, the Wadströms Exploranation Laboratory[1] has been developed as a scientific communication space for the the public to explore and interact with scientific data. In this paper, we focus on two interactive installations that could leverage the potential of exploranation as a pedagogical tool to foster increased climate awareness and action. Recent evidence for communication around climate change issues highlight the importance of conveying climate change at scale [4]. Past research has shown that while immersive climate change visualization (e. g., in a dome-theater movie) can foster initial reflections, interactive exhibits have been shown to actively and positively influence sense-making [3]. The exploranation laboratory aims to provide the general public with such opportunities through the following two example installations.

3.1 The Globe

The first installation pertaining to climate change and directly visible when entering the Wadströms Exploranation Laboratory is "The Globe" (see Fig. 1). It consists of a 1.5 m diameter sphere with a dual OmniFocus projection system consisting of two Barco F90 4K13 Laser-Phosphor projectors that illuminate the sphere from within via two 90 degree angled special lens systems. The system offers a 11.6 Mpix resolution at 25,000 lumens and is developed by Elumenati.[2] With the table-sized display postioned in front of the globe, visitors can manipulate which variables and models are displayed on the globe and, when relevant, scroll through time to view the direct impact of climate change on the planet. The table-sized display also offers basic manipulations to rotate the earth so as to focus attention on a specific region. The implemented visualization system is based on WorldViewer[3] and the system visualizes datasets and models from the Science On a Sphere dataset catalog,[4] which provides datasets for globe-shaped visualizations based on data sources such as NASA.

Building on the findings from past research on the benefits of immersive visual exploration of climate change and its consequences [3], this installation proposes to directly show the impact of climate change to visitors as they enter the laboratory space with a large spherical and immersive display of the planet itself. The shape of the display, beyond its obvious similarity to that of planet Earth itself, also makes it a central installation of the lab that immediately draws visitors' attention. The table-sized display adjacent to the globe provides users with interactive possibilities and explanations about what they are currently analyzing (see Fig. 1a). The visualized data is obtained directly from models and estimates computed by scientists working on climate change and its impact and causes. The table-sized screen allows users to navigate between different datasets and their associated explanations as well as rotate the Earth image or start/stop/change the pace of the animation when available (see Fig. 1a). The system allows users to switch between three main content types to explore that comprise earth cycles, climate models, and climate stories. Earth models give users the possibility to browse through different major cycles of the planet such as main ocean, land, carbon dioxide or food cycles. For instance, users can access a map of the average temperature over time or distribution and amplitude of temperature anomalies over time when compared to average temperatures for the same weeks or months

[1] https://visualiseringscenter.se/wadstroms

[2] https://www.elumenati.com/geodomes/geodome-globe-1-5m/

[3] https://www.elumenati.com/product/worldviewer/

[4] https://sos.noaa.gov/catalog/datasets/

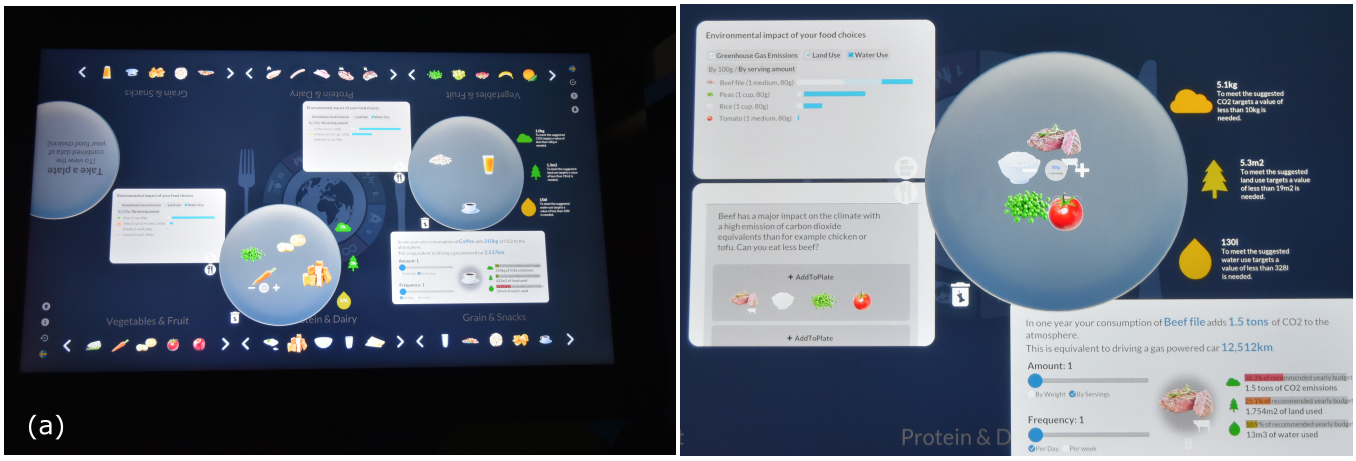

Figure 2: The Food on the Table exhibit. (a) shows how a visitor has visualized their own breakfast and lunch meals where they can explore the impact of each food type through the stacked bar chart. (b) displays how a visitor uses one of the predefined meals to analyze the impact of each food group on three variables of interest to discover that not all plant-based food is harmless to the environment, although beef appears to be the food source with the highest environmental impact.

between 2001 and 2010 (see Fig. 1a). When browsing through such datasets, users can rotate the earth's projection to focus on a specific point and control the speed and start of the animation that shows relative time differences afforded by possible comparison with the table-sized screen in front of the globe. This screen also displays information about the datasets, the measures, and their meaning to assist users in making sense of what they are analyzing. Second, the system allows visitors to explore different climate models part of the "Shared Socioeeconomic Pathways (SSPs)"[5] which have been used to help produce the IPCC Sixth Assessment Report.[6] They essentially provide narratives that describe different socio-economic developments based on different paths that humanity could take, from the greener one to the least sustainable one. Using the globe, visitors can explore the impact of different SSP scenarios to see how where we live now will evolve between 2020 and 2070 (see Fig. 1b), the air and sea temperature changes between 2015 and 2100, and the precipitation differences between 2015 and 2100. As before, visitors have access to explanations about the models they are exploring and the basic idea behind each of the available SSP scenarios. Finally, the installation allows users to experience climate stories which are short animations explaining the ozone recovery cycle, the evolution of extreme weather and its consequences, or the changing of the planet's climate and accompanying interactions with the sun and other terrestrial processes. Unlike the other two main components, these animations offer limited interaction possibilities beyond changing the geographic focus of the visualization and swiping to the next part of the visual story they are watching. These explanations are designed to be experienced as short animated explanations.

In conclusion, The Globe installation allows visitors to directly explore the consequences of climate change and the likely future(s) ahead based on different and evidence-based scenarios and models. However, as past research has shown, displaying the consequences of climate change is often unassociated with active behavioural change since people do not acknowledge overt links to their daily lives [4]. Although The Globe installation does explore some of the issues with our food and its industry and impact, it does not go into detail and does not permit further detailed exploration of the data, which the next presented exhibit aims to include.

[5] https://en.wikipedia.org/wiki/Shared_Socioeconomic_Pathways

[6] https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf

3.2 Food on the Table

To foster personal actions or increase understanding of local causes of climate change, it is often recommended to display climate change at scale, i. e., pointing to causes without pointing the finger to individuals but rather to the issue in itself. In partial response to this reason, "Food on the Table", a interactive horizontal touch table allows visitors to explore the impact of food habits on several parameters directly linked to climate change. Tackling the issue of food systems is particularly important for climate change as the global food system is directly responsible for crossing several planetary boundaries that were proposed to maintain our planet in a livable state [16]. While this issue is known and while plant-based diets have been promoted by scientists to reduce our global toll on the planet, habits have not yet changed to an extent enough to make a significant impact. We hypothesize that while the scientific knowledge has been gathered long ago, it has not yet reached the global population which can be incentivized to take action. We aim at bringing this knowledge to the public through our Food on the Table installation. The installation allows visitors to interactively derive solutions on their own or with the help of a guide, to reduce the environmental impact that food systems have on our planet.

The installation is composed of a 55-inch PREStop multi-touch table resting on a stand that is height-adjustable and tiltable. A HP Z1 G8 computer with a i9 11900 2.5 GHz CPU runs the program and is embedded into the stand. The software is developed with Unreal Engine version 4.26. The dataset is constructed by "Sustainaible Consumption – From Niche to mainstream" which produces research reports and datasets about sustainable food solutions. The dataset contains figures about the emissions of greenhouse gases, land- and water use of 218 different products and services in Sweden [8].

The installation requests visitors to take a virtual plate or two, and place food items that would correspond to their usual meals, or any meal options they would like to investigate. They subsequently view data about how their food choices will affect climate change based on three main measures: land use, water consumption, and carbon dioxide equivalents. When selecting an ingredient, users will see how many grams a portion is worth and can thus increase this portion to match the desired amount of food. For each plate on the table, each representing a meal or meals of one day, visitors can

view three icons representing the three variables of interests that are color-coded to represent the impact of their food choices. A close inspection on Fig. 2a shows that the second plate is associated with a high recommended water budget while land use and carbon dioxide equivalents are within acceptable measures. The Food on the Table exhibit also shows and uses classical pre-made meals to explore the impact of food that people would consider consuming in their daily lives. In Fig. 2b, a classic meal is displayed that contains peas, beef, rice and a tomato. It can be observed immediately that the three indicators of interest are now shaded in orange. In order to detect which ingredient is driving any of the three variables, users can click on the button with a bar chart to obtain detailed specific values for each of the plated ingredients. In doing so, we can see in Fig. 2a that the cup of coffee is the food agent that drives water consumption upward. Similarly, in Fig. 2b, by clicking on this button, we see the stacked bar chart for each ingredient on the plate and it allows us to detect that beef uses most resources overall, while peas are responsible for the highest water consumption, which makes frequent consumption of these two foods potentially unfavourable in considering actions to fight climate change.

In conclusion, Food on the Table provides visitors with the possibility to explore a dataset communicating the impact of different food items based on locally-computed data. It allows users to examine different variables of interest for climate change and how they are affected by different meal options in order to interactively derive food consumption solutions to act against climate change instead of merely passively realizing the consequences of climate change, without any reflections on future behaviors.

4 Research opportunities for visualization and climate change communication

The design of the presented novel installations are based on considering how exploranation can communicate elements of climate change in promoting reflection and action. In doing so, they raise new research questions in relation to pedagogy and interactive visualization design for mass audiences.

4.1 Designing with different levels of scaffolding in mind

In trying to communicate the complexity of climate change and given the diversity of science centers' audiences, we have embedded multiple levels of guidance and scaffolding in these two exhibits. The Globe proposes three different levels of guidance to explore data, from raw data exploration, to animated data stories, and integrating didactically-intended simulations. Food on the Table relies mostly on participants' interactive explorations to discover the impact of food on the planet. How each different scaffolding level is effective in communicating climate change and for what type of audience requires empirical investigations. Such investigation will allow us to generate knowledge on the potential role of scaffolding elements for interactive visualizations of climate change with diverse audiences. In doing so, we will obtain results that allow us to reflect on and inform the design of exploranative systems of climate change for the general public.

4.2 Investigating the pedagogical power of Exploranation

Within the context of the major societal topic of climate change, we will evaluate the potential pedagogical power of exploranation as a communication paradigm. A large proportion of research on climate change communication to date has focused on direct messaging to the population, through text, visualization, or images, but does not often evaluate the pedagogical benefits (and limitations) of free and guided exploration of scientific datasets. We will address this in future work by, for instance, studying the impact of Food on the Table when compared to more direct communication through qualitative studies conducted with groups of visitors. We also believe that studying visitors' interactive patterns, and the motivation behind their exploration of the data [7] might lead us to better understand how different visitor engagement situations contribute to communicating complex climate change issues.

4.3 Studying audience segmentation in visualizing climate

A "one size fits all" model of communication about climate change is unlikely to be the key to challenges in communicating climate change or an igniter of behavioral shift [12]. As such, implementing several interactive installations focusing on different aspects of climate change (ranging from representing impact to representing cause) in public science centers offers a chance to adopt audience segmentation research [12] to gain more insight into the influence of climate change communication on public audiences. Audience segmentation refers to clusters of homogeneous individuals based on psychological and/or behavioral traits. To the best of our knowledge, large samples have only been used in English-speaking countries (Australia, North America, India) [5], and have concentrated on very direct messaging e. g., support for specific policies [5]. Thus, the present work offers new possibilities to study how such profiles and segments translate to exploratory and interactive installations that communicate climate change with scientific visualization rather than only measure public support for specific policies.

4.4 Intergenerational engagement and learning

Climate change mitigation is infused with political and ideological stances. As such, perceiving climate communication is influenced by preknowledge and personal worldviews. Since children are often less politically-oriented than older generations, they might be more susceptible to receiving and adopting mitigating actions that serve to, in turn, inspire older generations [10]. Such transmission of knowledge and practices between generations is called intergenerational learning. Museums and science centers have often been considered relevant parent-to-child or grandparent-to-child intergenerational learning spaces [15]. It follows, that intergenerational learning experiences might be a purposeful position from which to study climate change communication and mitigation. The Wadströms laboratory presents unique possibilities to observe and consider how exploranation might provide intergenerational pathways for discussing and activating engagement and learning about climate.

5 Conclusion and Implications

This paper has described two interactive visualization exhibits designed in accordance with the emerging paradigm of exploranation. Public visitors' interaction with these visualizations affords opportunities to access and confront underlying principles of the climate crisis. Leveraging such exploranative scenarios in public spaces, can be used to mitigate interventions for societal action in response to climate change. Our future work will consider the role of exploranation in visualization pedagogy by systematically investigating public interaction with these exhibits to empirically measure their impact.

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REFERENCES

[1] H. Akiba, C. Wang, and K.-L. Ma. Aniviz: A template-based animation tool for volume visualization. *IEEE Computer Graphics and Applications*, 30(5):61–71, 2010. doi: 10.1109/MCG.2009.107

[2] L. Archer, E. Dawson, A. Seakins, J. DeWitt, S. Godec, and C. Whitby. "i'm being a man here": Urban boys' performances of masculinity and engagement with science during a science museum visit. *Journal of the Learning Sciences*, 25(3):438–485, 2016. doi: 10.1080/10508406.2016.1187147

[3] A. G. Ballantyne, V. Wibeck, and T.-S. Neset. Images of climate change–a pilot study of young people's perceptions of ict-based climate visualization. *Climatic change*, 134(1):73–85, 2016. doi: 10.1007/s10584-015-1533-9

[4] A. Corner, R. Webster, and C. Teriete. Climate visuals: Seven principles for visual climate change communication (based on international social research). *Climate Outreach. Corner A. Webster R. Teriete C*, 2015.

[5] D. W. Hine, W. J. Phillips, R. Cooksey, J. P. Reser, P. Nunn, A. D. Marks, N. M. Loi, and S. E. Watt. Preaching to different choirs: How to motivate dismissive, uncommitted, and alarmed audiences to adapt to climate change? *Global Environmental Change*, 36:1–11, 2016. doi: 10.1016/j.gloenvcha.2015.11.002

[6] G. Höst, K. Palmerius, and K. Schönborn. Nano for the public: An exploranation perspective. *IEEE Computer Graphics and Applications*, 40(2):32–42, 2020. doi: 10.1109/MCG.2020.2973120

[7] G. E. Höst, K. J. Schönborn, H. Fröcklin, and L. A. E. Tibell. What biological visualizations do science center visitors prefer in an interactive touch table? *Education Sciences*, 8(4), 2018. doi: 10.3390/educsci8040166

[8] A. C. Kanyama, N. Baraka, R. Benders, M. Berglund, F. Dunér, R. Kok, and R. L. I. Losada. Analysis of the environmental impacts of 218 consumption items. *MISTRA Sustainable Consumption*, 2019.

[9] E. L. Kuster and G. A. Fox. Current state of climate education in natural and social sciences in the usa. *Climatic Change*, 141(4):613–626, 2017. doi: 10.1007/s10584-017-1918-z

[10] D. F. Lawson, K. T. Stevenson, M. N. Peterson, S. J. Carrier, R. L Strnad, and E. Seekamp. Children can foster climate change concern among their parents. *Nature Climate Change*, 9(6):458–462, 2019. doi: 10.1038/s41558-019-0463-3

[11] K.-L. Ma, I. Liao, J. Frazier, H. Hauser, and H.-N. Kostis. Scientific storytelling using visualization. *IEEE Computer Graphics and Applications*, 32(1):12–19, 2012. doi: 10.1109/MCG.2012.24

[12] E. M. Markowitz and M. L. Guckian. 3 - climate change communication: Challenges, insights, and opportunities. In S. Clayton and C. Manning, eds., *Psychology and Climate Change*, pp. 35–63. Academic Press, 2018. doi: 10.1016/B978-0-12-813130-5.00003-5

[13] M. C. Monroe, R. R. Plate, A. Oxarart, A. Bowers, and W. A. Chaves. Identifying effective climate change education strategies: A systematic review of the research. *Environmental Education Research*, 25(6):791–812, 2019. doi: 10.1080/13504622.2017.1360842

[14] S. Schwan, A. Grajal, and D. Lewalter. Understanding and engagement in places of science experience: Science museums, science centers, zoos, and aquariums. *Educational Psychologist*, 49(2):70–85, 2014. doi: 10.1080/00461520.2014.917588

[15] D. M. Sobel, S. M. Letourneau, C. H. Legare, and M. Callanan. Relations between parent–child interaction and children's engagement and learning at a museum exhibit about electric circuits. *Developmental Science*, 24(3):e13057, 2021. doi: 10.1111/desc.13057

[16] M. Springmann, K. Wiebe, D. Mason-D'Croz, T. B. Sulser, M. Rayner, and P. Scarborough. Health and nutritional aspects of sustainable diet strategies and their association with environmental impacts: a global modelling analysis with country-level detail. *The Lancet Planetary Health*, 2(10):e451–e461, 2018. doi: 10.1016/S2542-5196(18)30206-7

[17] K. Steentjes, N. F. Pidgeon, W. Poortinga, A. J. Corner, A. Arnold, G. Böhm, C. Mays, M. Poumadère, M. Ruddat, D. Scheer, et al. European perceptions of climate change (epcc): Topline findings of a survey conducted in four european countries in 2016. 2017.

[18] S. Wang, A. Corner, D. Chapman, and E. Markowitz. Public engagement with climate imagery in a changing digital landscape. *Wiley Interdisciplinary Reviews: Climate Change*, 9(2):e509, 2018. doi: 10.1002/wcc.509

[19] S. Wang, Z. Leviston, M. Hurlstone, C. Lawrence, and I. Walker. Emotions predict policy support: Why it matters how people feel about climate change. *Global Environmental Change*, 50:25–40, 2018. doi: 10.1016/j.gloenvcha.2018.03.002

[20] L. Whitmarsh, S. O'Neill, and I. Lorenzoni. Public engagement with climate change: what do we know and where do we go from here? *International Journal of Media & Cultural Politics*, 9(1):7–25, 2013. doi: 10.1386/macp.9.1.7_1

[21] A. Ynnerman, J. Löwgren, and L. Tibell. Exploranation: A new science communication paradigm. *IEEE Computer Graphics and Applications*, 38(3):13–20, 2018. doi: 10.1109/MCG.2018.032421649

[22] A. Ynnerman, T. Rydell, D. Antoine, D. Hughes, A. Persson, and P. Ljung. Interactive visualization of 3d scanned mummies at public venues. *Commun. ACM*, 59(12):72–81, dec 2016. doi: 10.1145/2950040