CrossMark

Images of climate change – a pilot study of young people's perceptions of ICT-based climate visualization

Anne Gammelgaard Ballantyne[1,2,3] · **Victoria Wibeck**[1,2] ·
Tina-Simone Neset[1,2]

Abstract Climate change can be difficult for laypeople to make sense of, because of its complexity, the uncertainties involved and its distant impacts. Research has identified the potentials of Information and Communication Technologies (ICT) for visualizing and communicating climate change to lay audiences and thus addressing these communication challenges. However, little research has focused on how ICT-based visualization affects audiences' understandings of climate change. Employing a semiotic framework and through a combination of focus group interviews and mindmap exercises, we investigated how Swedish students make sense of climate messages presented through an ICT-based visualisation medium; a dome theatre movie. The paper concludes that visualization in immersive environments works well to concretize aspects of climate change and provide a starting point for reflection, but we argue that the potential to add interactive elements should be further explored, as interaction has the potential to influence meaning-making processes. In addition, audiences' preconceptions of climate change influence their interpretations of climate messages, which may function as a constraint to climate communication.

1 Climate change: a communication challenge

The role of the public in responding to the challenges of climate change is increasingly being emphasized in climate science and policy debates (Joffe and Smith 2013). In particular, it has been argued that the public can contribute to climate change mitigation through lifestyle changes and "green consumerism", or through exercising political influence by supporting climate-friendly policies (e.g. Whitmarsh et al. 2013; Lowe et al. 2006). A key concept in these

✉ Anne Gammelgaard Ballantyne
anne@auhe.au.dk

1   Department of Thematic Studies - Environmental Change, Linköping University, Linköping, Sweden

2   Centre for Climate Science and Policy Research, Linköping University, Linköping, Sweden

3   Department of Business Development and Technology, Aarhus BSS, Aarhus University, Birk Centerpark 15, DK-7400, Herning, Denmark

debates is "public engagement", which refers to the active participation of the public in learning and action addressing climate change (Wolf and Moser 2011).

Many scholars agree that public communication about climate change can foster public engagement and is thereby integral to mitigating and adapting to the changing climate (e.g. Spence and Pidgeon 2010). Knowledge of various communication approaches and tools that will enable stakeholders from the individual to political levels to make informed decisions and prioritize actions for adapting to and mitigating climate change is arguably becoming increasingly important. However, the abstract nature of climate change, the complexity of scientific data, the many actors with different opinions and stakes, a media debate that often emphasizes conflict and disagreement, and that most people perceive climate change as distant in time and space, make such communication challenging (Lorenzoni et al. 2007; Pidgeon and Fischhoff 2011; Sheppard 2012).

A tempting way to address these challenges would be to increase the amount of information provided. However, research has paradoxically identified yet another constraint to climate change communication, namely, that of "climate fatigue" resulting from information overload (Semenza et al. 2011). This suggests that more information is not a viable way to overcome the problem. Hence, rather than starting from an "information deficit" model of climate change communication, which would treat providing more science-based information as a remedy for lack of public engagement (Brossard and Lewenstein 2009; Nisbet and Scheufele 2009), this paper takes its point of departure in a semiotic framework that "is interested in how things come to gain meaning for individuals, and how these meanings are a product of the cultures and worldviews from where they originated" (O'Neill and Hulme 2009: 403).

Recent research has pointed towards the benefits of visualizing climate science for lay audiences using information- and communication technologies (ICT) to "create visual images of the causes and effects of climate change" (Neset et al. 2009: 5). ICT-based climate visualization is claimed to offer a way to address some of the challenges identified in the climate communication literature (Wibeck et al. 2013; Moser 2010; Nicholson-Cole 2005). Examples of such visualizations include advanced computer graphics, 3D landscape visualizations or immersive environments, such as digital planetariums, or other convex large-screen displays (Fraser et al. 2012; Sheppard 2012). ICT-based visualization is becoming popular in science communication, not least since the rapid development of the interactive entertainment industry makes advanced visualization tools increasingly affordable and accessible to a growing number of communicators (Wibeck et al. 2013). However, little research has been focused on how different target groups make sense of ICT-based visualization of problems, goals, and action alternatives (Sheppard et al. 2011; Salter et al. 2009; Neset et al. 2009).

This paper addresses this knowledge gap by reporting findings from a pilot study of how Swedish high-school students make sense of climate change messages presented through an ICT-based visualization medium in an immersive environment. The paper contributes to the emerging case-specific and audience-specific research into climate change communication, called for in the climate change communication literature (e.g. Moser 2010; Whitmarsh and Lorenzoni 2010). Its focus is on Swedish high-school students since teenagers and young adults are claimed to be particularly sensitive to information on climate and other sustainability challenges (Linnér 2005).

2 A pilot case of ICT-based climate visualization: A Warmer World

Since 2009, Linköping University researchers have collaborated with Norrköping's Visualization Centre-C and the Swedish Meteorological and Hydrological Institute to create

presentations on climate change. As an example of ICT-based climate visualization targeting an audience of young people, the 30-minute movie *A Warmer World*[1], launched in 2011, is the focus of this paper.

Based on a series of modules supported by a narrative, the movie provides an introduction to climate change causes and impacts and to the need for adaptation and mitigation options. It builds on data for different climate scenarios, sea level rise, and greenhouse gas (GHG) emissions for various food products. The movie starts by visualizing the greenhouse effect and the *causes* of climate change, for example, population growth and historical carbon dioxide emissions. The international climate change negotiations are addressed when GHG emissions are represented as 3D volume bar charts (Fig. 1).

Three different ways of accounting for, and hence distributing, responsibility for GHG emissions, are represented: (1) total current emissions per country, implying that large GHG-producing countries, such as the USA and China, account for approximately 50% of total global emissions; (2) cumulative historical emissions since the 1860s, which puts a greater emphasis on early industrialized countries such as the UK and Germany; or (3) accounting for emissions per capita per country, which significantly reduces the responsibility of countries such as China and India. This is followed by an animation of tipping points, a concept frequently used in the climate change discourse (Russil and Nyssa 2009), after which the entire dome surface is converted into a thermometer, showing the maximum global annual mean temperature for various scenarios, and the possible decreases occurring with various policy goals.

The *impacts* of climate change are represented in the changing global temperatures in three climate scenarios, SRES scenario A2, A1B, and B2 (Nakicenovic and Swart 2000), in three simultaneously displayed globes showing the annual mean temperatures from 1960 to 2100, emphasizing the role of scenarios and displaying the uncertainty range between the most intensive and the most sustainable emission scenarios. Other examples of impacts include a geovisual representation of global population density and the areas near oceans that are below one meter in elevation and could potentially be inundated, followed by examples of the *adaptation needs* of megacities around the world and of island states that are particularly vulnerable to climate change impacts.

The film stresses *mitigation options* and *personal actions* that can be taken to reduce climate impact. Following an examination of global energy consumption, several issues, including individual food consumption, clothes production, household energy consumption, and air travel, were addressed.

3 Methodology

The focus of this study is on how messages come to gain meaning for members of a target audience. Theories of semiotics provide a framework for understanding how systems of meaning employed in visual communication are communicated and interpreted. Additionally, it "can contribute to a more complete understanding of how communication in general operates" by emphasising the meaning perspective in the context of visual communication

---

[1] The digital dome theatre in the Norrköping visualization centre covers 165° of a sphere with a 15 m diameter with a total screen surface of approximately 300 square meters with six separate projectors, which enables the entire screen to be used for images, featuring a total resolution of 3710 × 3180 pixels. The production was based on the interactive 3D visualization software IceDome.

Fig. 1 GHG emissions represented as 3D volume bar charts

(Moriarty 1996: 186). The relationship between signs and meaning is a fundamental aspect of communication theory and it provides a framework for understanding interpretation as a core facet of communication, by accentuating the active role of the audience (Fiske 2011).

3.1 Semiotics: the language of visuals

Semiotics is the study of how signs work and how patterns of meaning are formed based on sign stimuli. Signs can be broadly defined to encompass words as well as visuals and sounds and function as tokens for something else, representing an idea or reality in the reader's mind (MacEachren et al. 2012; Eco 1986).

Developing the ideas of early linguistic semiotics, Barthes (1977) presented a conceptual framework for the rhetoric of images, where he outlined different levels of meaning. This encompasses denotation, defined as the literal message, and connotation, defined as the symbolic, culturally coded message linked to the literal message. Connotations are not purely subjective, but influenced and determined by cultural codes constituting the reader's reality and perspectives. A semiotic approach to (visual) communication emphasises the active role of the audience in the interpretation process and can be used as a framework for understanding how graphic representations work (MacEachren et al. 2012; Moriarty 1996).

This study was designed to investigate how young people interpret climate change messages presented via ICT-based visualization. To capture the social dimension, we conducted

focus group interviews with Swedish high-school students (16-19 years of age) from a three-year social science education program after watching *A Warmer World* in the dome theatre at Norrköping Visualization Centre.[2] To contextualize this analysis, one sub-question asks: What is the purpose of the movie from the sender's perspective? This question sought to outline the movie creator's intended meanings with the movie messages and provides a point of comparison for our analysis of the students' interpretations of the movie messages. Recognizing the need to understand the target audience's preconceptions of climate change (e.g. Moriarty 1996; Wibeck et al. 2013) and provide a context for the students' interpretations of the movie messages, a second sub-question asks: How do the students generally perceive the concept of climate change?

3.2 Investigating meanings

3.2.1 Focus group interviews

Taking into account the semiotic point that meanings are socially and culturally constructed, focus group interviews were chosen as the main method. Focus groups are forwarded as appropriate for investigating how meaning patterns are formed in a social context (Halkier 2008; Wibeck et al. 2007). Although limited in scope, the set-up of this study allows in-depth insights into how sense making occurs in interaction between participants in a focus group discussion (Marková et al. 2007).

We held a total of three focus group interviews, and each focus group consisted of 5–7 students. In total, 18 students, nine girls and nine boys in secondary education, participated in in-depth focus group interviews. The focus groups were relatively homogeneous and consisted of students of the same age from the same geographical area, all of whom knew each other from school.

A moderator, whose role was to stimulate discussion and ensure that all points from the interview guide were covered, facilitated the focus group interviews. The group discussions were semi-structured to allow the participants to set the agenda and discuss what they regarded as important messages from the movie.

We conducted a thematic content analysis (e.g. Halkier 2008; Wibeck et al. 2007) in which we systematically examined and coded the interview transcripts for salient themes constituting the main content categories. These overall categories were subsequently divided into sub-categories, and interview quotations were identified to represent their content. We combined the content analysis with a frequency analysis, counting recurrent instances of participants' references to particular visuals. This provided an impression of the most significant representations from the participants' perspectives and helped us identify patterns of the students' interpretations of the movie content.

3.2.2 Mind-maps

Before watching the movie, all students who visited the dome theatre were invited to participate in an online mindmap exercise. This exercise provided an overview of the students'

---

[2] As a service to the teachers and students, all students from the education program were invited to the dome presentation, not only those participating in the focus groups included in the study. In total, approximately 90 students visited the dome presentation.

unprompted associations with climate change to contextualise the focus group results. The term "climate change" was inserted at the centre of the mindmap chart, and students were enabled to add any number of links and individual entries describing their associations with climate change.

We analysed a total of 52 individual mindmaps ranging from 7 to 34 single entries, consisting of words or expressions. We conducted a word count to identify frequent associations and analysed the first entries, to get a sense of the students' initial associations. Finally, we conducted a thematic analysis of the mindmap associations categorising the students' entries into salient themes.

3.2.3 Interview

To provide a point of comparison to the audiences' interpretations of the movie messages, we conducted an interview with one of the scriptwriters of *A Warmer World*. The interview was transcribed and analysed for themes regarding the expressed intentions of the movie.

4 Results

4.1 The scriptwriter's perspective

The movie *A Warmer World* serves two main purposes: 1) to educate high-school students about climate change, by visualizing complex or abstract aspects of climate change and giving them a good starting point for discussion and reflection, and 2) to induce a sense of agency by pointing out that mitigating climate change is not just a political responsibility, but also an individual responsibility. Through a combination of music, visuals, and narratives, the movie aims to illustrate the impacts and causes of climate change and, based on this, present the audience with individual action alternatives. The visual representations are meant to offer insights into climate change causes and impacts, the political complexity and individual action alternatives, but also to highlight the correlations between these. In addition, the movie's creators wished to move away from the "doomsday" framing of climate change and instead present the students with a more nuanced view of climate change.

4.2 Preconceptions of climate change

Analyzing the mindmaps, we found that most of the students' associations to climate change could be grouped into a category labelled Impacts (over 40% of all entries belonged to this category). This was followed by the category Causes (20% of the entries), while the category Actors only encompassed approximately 4% of the entries.

The most frequent word for the entire group of respondents was *greenhouse effect*, which was present in more than half of the mindmaps, and 17 of the 52 students having this term as first entry in their individual maps. The second most frequent first entry was *carbon dioxide* or *carbon dioxide emissions*, which in total accounted for six first entries.

The mindmap analysis suggests that the student audience invited to the dome theatre had a previous understanding of climate change much in line with how Swedish mainstream media portray climate change, i.e. through words such as *greenhouse effect* and *carbon dioxide* (Olausson 2009), which could be considered somewhat mirrored in these mindmaps.

4.3 Perceptions of climate change

To gain an overview of the focus group participants' general perceptions of climate change after having seen the movie, the first question they were asked in the focus group interviews was "What comes to mind when you hear the words climate change?" In all focus groups, this question resulted in a combination of single-word associations and longer discussions among the participants, where the most frequent themes were: a) Impacts b) Causes, and c) Actors.

The most prevalent pattern across the three focus groups was the recurrent mentions of climate change *impacts*. The dominant semantics relating to impacts of climate change linked to natural disasters and polar bears/melting ice. As regards the natural disasters, this was expressed through short statements such as: "But that would kind of be the end of the world", "natural disasters", "more tsunamis", "The USA will kind of be flooded, Manhattan", and "Worse weather, more catastrophes". Polar bears and melting ice were other frequent associations. The participants did not really discuss these, but made statements apparently perceived as common knowledge in the group: "Polar bears", "The ice melts", "Sad little polar bears who have no place to live", and "And then a polar bear who sits there and is sad". Despite the somewhat ironic or humorous tone in some of the comments, the fact that the participants unprompted mentioned polar bears testifies that it was a primary connotation positioning climate change impacts as spatially distant from the participants (cf. Doyle 2007; Manzo 2010).

When talking about *causes* of climate change, the participants mentioned carbon dioxide, means of transportation, and industrialization as main associations with climate change. Two of the groups maintained an intensive discussion on global development in relation to industrialization. Interestingly, they did not relate industrialization to Sweden or the Nordic countries, but instead the discussion pointed towards future development in unspecified developing countries, creating a personal (and geographic) distance. Carbon dioxide emissions and transportation were only mentioned in passing, but not further elaborated or discussed.

The participants also discussed various actors playing a role in the climate debate, ranging from Al Gore and COP15 in Copenhagen to actors involved in international, political conflicts relating to oil, money, and power. However, they did not bring up their own behaviour and actions when asked about their general associations with climate change. Nor did they indicate that responsibilities of individuals (e.g. themselves) were among their immediate considerations on the topic.

In sum, the participants' understanding of climate change seemed structured around iconic images such as suffering polar bears and their terminology was centred around natural disasters and "the end of the world", powerlessness, and industrialization, framing climate change as a distant phenomenon with severe impacts that do not relate to their social context. A recent study of the links between climate change images and emotional responses suggests that images of extreme weather can evoke feelings of helplessness and potentially lead to disengagement (Nerlich and Jaspal 2014). With the aim of highlighting individual actions that can be taken to mitigate GHG emissions, the movie did not display such images and notably, a main purpose of the movie was to move away from the doomsday discourse that has characterized the climate change debate. Nevertheless, our data indicate a meaning gap between the target audience's perceptions of climate change and the movie's purpose.

4.4 Interpretations of the movie A Warmer World

4.4.1 Concretizing the abstract

One of the movie objectives was to create visual representations that could help the audience gain a deeper understanding of climate change issues. In analysing how the participants made sense of the movie, we found that they recurrently referred to how the movie helped them improve their understanding by concretizing aspects of climate change. In particular, our analysis identified three interrelated sub-categories all relating to "concretization", namely *making complexity visible*, *clarifying and/or providing an overview*, and *making climate change tangible*. Table 1 includes quotations from the focus groups illustrating each of these sub-categories.

The focus group participants frequently brought up the visual representation that illustrates three globes in three different ways of calculating GHG emissions (Figure 1). They generally agreed that this specific illustration helped them understand a complex aspect of climate change and also gain a better overview of the rationales underlying various international political discussions and disagreements. The participants also highlighted visual representations that somehow surprised them, such as the illustration of emissions associated with different food categories, where the circle representing "beef" takes up most of the screen surface in the dome theatre. Other salient visuals in the discussions were a comparison of climate scenarios, a representation of global population density, and an animation of global air traffic. Such representations were emphasised because they surprised the participants, provided them with new knowledge or deeper understandings, and tended to spark discussion in the focus groups, suggesting that deeper reflection was developed in the social setting of the focus group interviews. Well aligned with the movie objectives, the movie therefore functioned as a starting point for discussion, and the interactions between the focus group participants increased their reflections on the movie.

In general, the participants linked understanding to movie visuals by stating e.g. that the movie "showed" complex aspects of climate change or by referring to specific visuals that made an impression (c.f. Table 1). The link between visual representations and comprehension is further amplified in the second category. The participants frequently explained that the visuals provided them with an overview or helped them see aspects of climate change more clearly. Notably, they repeatedly used a form of the word "see" in relation with "overview" or "clear". The accentuation of seeing suggests that visually communicating a message had a positive influence on the participants' reception of the message. This relates to the third category that comprises examples of references to tangibility. Expressions such as "the columns", a curve that "went straight up" or "circles that took over the screen" are examples of specific references to visual representations in the movie, indicating that the respondents benefitted from the visuals because it helped them understand e.g. a comparison by enabling them to see the differences in size between two circles or columns. As such, the movie provided the participants with concrete points of reference that functioned as starting points for reflection.

4.4.2 Responsibility and actors

When asked to identify the overall message of the movie, all groups identified the complexity of international collaborations and the particular importance of individual responsibility in reducing CO_2 emissions as key messages, which are well aligned with the movie's communicative objectives. Remarkably, the participants' general perceptions of climate change did not reveal connotations relating to individual action. Nonetheless, further investigating their

Table 1 Examples of "concretization"

Making complexity visible

"5: But I think **it explains really well**, for example, how scientists work, and with these different scenarios and kind of why they do not…
4: Yes, how they think
5: Or why they have not achieved anything at the conferences
4: It is **easier to see it**…you cannot just look at it one way, but **there are different ways to look at it**" (FG 1)

"But when they **showed** how much countries emit and how it is distributed, then one could kind of really **understand** what **it looks like**, and I think that was very good" (FG 2)

"All the visualization was so well done, **it really showed** how… I mean you get some of the figures in the books as well, on paper, but then maybe you do not **understand how large scale it really is**" (FG 2)

The focus group participants emphasised visual representations that helped them understand the complexity of climate change.
In their discussions, understanding is often linked to seeing, showing, and looking, indicating a connection between comprehension and visual representations.

Clarifying and/or providing an overview

"3: Everything just became a little **clearer**…
1: Yes, exactly!
2: Yes it was actually much **clearer**. I really loved the one where you **saw** the globe with all the bars coming up – then you really **see it very clearly**" (FG 2)

"The exciting thing was to **see** – I mean, we just **saw** that for instance Australia emitted more when it was per person – but you did get a **better overview** with these different bars that came up." (FG 2)"You get a **better overview** – otherwise you only see a chart and then ignore it, but now it was much **easier to see.**" (FG 2)

"Yes, and it was good that **they showed** the bars for different countries. That was interesting. It made things **clearer** than if you only see them on paper" (FG 3)

"I thought, when you **saw** these planes, I mean, I did not know that it was that much – or you get a **better idea** of it" (FG 3)

"But I think that everyone should **see** these **concrete examples** as well… what you can do…" (FG 3)

The focus group participants highlighted that the movie gave them a clear idea and a better overview of climate change issues.
The strong emphasis on "clear" could indicate that climate change related issues became less abstract through the visualizations.
Again, seeing is accentuated in correlation with gaining an overview or getting a better and clearer idea of climate change aspects suggesting that actually seeing the visual representations has a positive influence on the respondents comprehension of climate change aspects.

Making climate change tangible

"Yes, it filled its function, clearly. With the increase in population against carbon emissions as well, and **it just went straight up**, like this". (FG 1)

"2: The USA and China together made up 50 % of the world's carbon emissions, or what was it – something like that – and it really is…. **When those columns stood…**
1: Yes, awesome
2: And how, indeed, very **much higher** than all the others…
5: Yes, and how little Sweden emitted, really" (FG 2)

"And what I always think is so cool, I have seen many charts on this, it's that the population has increased and so has the carbon dioxide… the carbon dioxide

In discussing the movie, the focus group participants referred to specific visual representations and how e.g. differences and comparisons were illustrated.
The visual representations seem to have given the participants a tangible, concrete point of reference as a starting point for joint reflection.

Table 1 (continued)

has just gone like this and then the industrialization
and then **it just went straight up**… I really thought
it did like this, and you really *see* how it has changed
in recent times as well" (FG 2)

"You got a little more details. Here, I think about the food as
well. I did not know that there was such a **huge difference**
between meat and carrots, for example, so… you **got a
little deeper**…" (FG 3)

"4: I remember that stuff about the food as well, how much
carbon dioxide and stuff like that
5: Yeah, **those circles, the diagrams**
3: The steak
4: Yeah**, the steak just took over the entire screen**
1: Yeah, you had not thought about that a lot" (FG 3)

"It is **easier** when you **see** images. It became real, instead
of just numbers, I think" (FG 3)

discussions of this theme revealed that their perceptions were more complex than these initial denotations of the movie elements suggested. Despite them identifying individual responsibility as a key message, the dominant discourse revealed a limited sense of agency among the participants. As such, they projected the responsibility onto other actors, for example, their parents, politicians, and actors in other countries:

> 5: And the pressure is greatest on the grown-ups. I mean, they are the ones who buy the food, and they are the ones who drive cars.
> (focus group 2)
> 1: I guess it is politics that (4: Yeah) makes the biggest difference, really
> 5: But they are doing too little
> 1: Yeah [inaudible], that's where change is needed (5:Yes)
> 2: I think the USA needs to do something about this
> (focus group 3)

In addition, some of the participants expressed a sense of powerlessness and complained that it is difficult to know what to do as individuals. Furthermore, others questioned the effects of individual behaviour, saying that they were only "small players". This corresponds well with their preconceptions of climate change, emphasizing impacts so severe or geographically distant that they as individuals feel powerless.

The projection of responsibility onto others could also be explained by the age of the participants. They are high-school students, still living at home and at this stage in their lives, they are not used to be left in charge of any major household decisions. Accordingly, it could be seen as an expected response for them to project responsibility onto e.g. their parents. On the other hand, discussions about individual action and responsibility could have been expected from this particular audience, i.e. high school students at a social science programme, which includes a science course on the role of natural science in society in relation to sustainable development, and the environmental impacts of different lifestyles. Moreover, the curriculum for the Swedish upper secondary school states that: "Environmental perspectives in education should provide students with insights so that they can not only contribute to preventing harmful environmental effects, but also develop a personal approach to overarching, global environmental issues. Education should

illuminate how the functions of society and our ways of living and working can best be adapted to create sustainable development" (Skolverket 2013, p. 6). However, our data indicate that media, popular culture and popular science representations of climate change had a larger impact on the students' sense-making. At the denotative level of interpretation, the participants were able to identify individual responsibility as a key message; however, their group discussions revealed that their connotations were still aligned, *not* with the movie's purpose, but with their preconceptions of climate change as something distant that does not directly relate to themselves. This points to the significance of understanding interpretation processes and supports the notion of an audience's prior knowledge affecting their interpretation of signs (Moriarty 1996).

5 Discussion and conclusions

Our study, although limited in scope, supports the argument that ICT-based visualization can concretize certain aspects of climate change (Joffe and Smith 2013; Schneider 2012). The focus group participants asserted that the movie gave them a better understanding of more complex aspects of climate change. Our results indicate that visual representations work well as a starting point for dialogue and reflection, by clarifying and making abstract climate science tangible, and by opening up more ways of seeing e.g. the complexities and uncertainties embedded in climate policy options.

Perceived spatial and temporal distance to climate change is another salient challenge often referred to in the climate change communication literature and message strategies with a local focus are often recommended to motivate and engage an audience (e.g. Spence and Pidgeon 2010; Wibeck 2014a, b). Our findings present that the students' initial associations with climate change concerned its severe impacts and causes. This, however, was not much discussed in the movie, but coincided both with the broader mindmap data from the larger group of students, with how the Swedish news media have reported on climate change, focusing on scientific consensus on the anthropogenic causes of climate change, extreme weather events and predictions of future catastrophes (Olausson 2009), and with Hollywood representations of climate change through movies such as The Day after Tomorrow (Lowe et al. 2006). The same tendency is evident with respect to the participants' unprompted focus on disaster narratives and polar bears along with their discussions of actors and responsibility that were undermined by feelings of helplessness. These perceptions clearly deviate from the movie objective, but are aligned with the mindmap data, suggesting that the participants' preconceptions of climate change function as a constraint to climate messages addressing individual responsibility. In this sense, climate visualization alone is not a sufficient manner to engage an audience and create a sense of individual responsibility and action.

The discussions among the focus group participants made them reflect on the messages presented in the movie, and made them develop new understandings in dialogue with their fellow students. Such joint meaning making often results from interaction between focus group participants deliberating on complex topics (e.g. Marková et al. 2007; Wibeck et al. 2007). However, a dome production such as the one examined here does not allow for interaction with and among audiences. Although the script makers strived to produce a movie which would engage and not only inform audiences, the very format of a movie for educational purposes could in fact be seen as an expression of an information-deficit approach to climate change communication. Thus, we argue that the potential to add interactive elements to facilitate reflection to the dome experience should be explored. Such interaction could take the form of interactive voting, involving the audience in the narrative, or presenting the film in its separate modules, leaving space for discussion.

Our study supports the semiotic notion of acknowledging the different layers of interpretation in message reception (Barthes 1977). The focus group participants' identification of the overall movie message was well aligned with the intended message as outlined by the scriptwriter. Yet, their continued discussions revealed more complex negotiations of meaning influenced by their preconceptions of climate change. Whereas the denotative level of interpretation seemed more easily aligned with the intended reading of the message, the connotative level was influenced by the participants' preconceptions of climate change. Contemplating the semiotic approach to communication, it is not surprising that interpretations are influenced by existing knowledge. As such, this situates climate change communication in a theoretical context that holds interpretation and meaning as principal elements influenced by contextual factors. To investigate the effects of communicative efforts, these factors, i.e. social context, prior knowledge and levels of interpretations, need be considered as part of the communication process and be embedded in the methodological design of climate change communication studies. In this light, climate visualization should not be seen as a simple way of transmitting a message, as visual communication is much more complex. This also supports the perspective of receivers as active participants in the communication (interpretation) process and underpins the semiotic notion that "meaning lies with the audience rather than with the text" (Moriarty 1996: 179).

In closing, our study illuminates four significant lessons for those interested in communicating climate change to young audiences via ICT-based visualization:

1. ICT-based visualization can be used to concretize abstract and complex aspects of climate change and serve as a starting point for dialogue and reflection.
2. Understandings of climate change are developed and elaborated in social settings, which underlines the importance of interaction as a communicative element.
3. An audience's preconceptions of climate change influence their interpretations of climate messages and may influence their interpretations of messages addressing e.g. individual responsibility.
4. Communication defined as a meaning-centred approach enables the uncovering of different layers of interpretation and provides a more nuanced understanding of communicative effects.

References

Barthes R (1977) Image, music, text. Fontana Press, London

Brossard D, Lewenstein B (2009) A critical appraisal of models of public understanding of science: Using practice to inform theory. In: Kahlor L, Stout P (eds) Communicating science: New agendas in communication. Routledge, New York

Doyle J (2007) Picturing the clima(c)tic: Greenpeace and the representational politics of climate change communication. Sci Cult 16:129–150

Eco U (1986) Semiotics and the philosophy of language. Indiana University Press, Bloomington

Fiske J (2011) Introduction to communication studies. Routledge, London

Fraser J, Heimlich J, Jacobsen J, Yocco V, Sickler J, Kisiel J, Nucci M, Jones L, Stahl J (2012) Giant screen film and science learning in museums. Int J Mus Manag Curator 27:179–195

Halkier B (2008) Fokusgrupper. Samfundslitteratur, Frederiksberg

Joffe H, Smith N (2013) How the public engages with global warming: A social representations approach. Public Underst Sci 22:16–32

Linnér B-O (2005) Att lära för överlevnad: utbildningsprogrammen och miljöfrågorna 1962 – 2002 [Learning for survival: educational programmes and environmental issues 1962-2002] Stiftelsen Etermedia i Sverige. Lund: Arkiv förlag

Lorenzoni I, Nicholson-Cole S, Whitmarsh L (2007) Barriers perceived to engaging with climate change among the UK public and their policy implications. Glob Environ Chang 17(3-4):445–459

Lowe T, Brown K, Dessai S (2006) Does tomorrow ever come? Disaster narratives and public perceptions of climate change. Public Underst Sci 15:435–457

MacEachren AM, Roth RE, O'Brien J, Li B, Swingley D, Gahegan M (2012) Visual semiotics and uncertainty visualization: an empirical study. IEEE Transactions on Visualization and Computer Graphics 18(12):2496–2505

Manzo K (2010) Beyond polar bears? Re-envisioning climate change. Meteorol Appl 17:196–208

Marková I, Grossen M, Linell P, Salazar OA (2007) Dialogue in Focus Groups: Exploring Socially Shared Knowledge. Equinox, London

Moriarty S (1996) Abduction: A Theory of Visual Interpretation. Commun Theor 6(2):167–187

Moser S (2010) Communicating climate change: History, challenges, process and future directions. WIREs Clim Chang 1:31–53

Nakicenovic N, Swart R (eds) (2000) Emission Scenarios. IPCC 2000 (pp. 570). Cambridge University Press, UK

Nerlich B, Jaspal R (2014) Images of Extreme Weather: Symbolising Human Responses to Climate Change. Science as Culture 23(2):253–276

Neset T-SS, Johansson J, Linnér B-O (eds) (2009) State of climate visualization. CSPR report 2009: 4

Nicholson-Cole S (2005) Representing climate change futures: a critique on the use of images for visual communication. Comput Environ Urban Syst 29:255–273

Nisbet M, Scheufele D (2009) What's next for science communication? Promising directions and lingering distractions. Am J Bot 96:1767–1778

O'Neill SJ, Hulme M (2009) An iconic approach for representing climate change. Glob Environ Chang 19:402–410

Olausson U (2009) Global warming - global responsibility? Media frames of collective action and scientific certainty. Public Underst Sci 18:421–436

Pidgeon N, Fischhoff B (2011) The role of social and decision sciences in communicating uncertain climate risks. Nat Clim Chang 1:35–41

Russil C, Nyssa Z (2009) The tipping point trend in climate change communication. Glob Environ Chang 19:336–344

Salter JD, Campbell C, Journeay M, Sheppard SRJ (2009) The Digital Workshop: Exploring the Use of Interactive and Immersive Visualisation Tools in Participatory Planning. J Environ Manage 90:90–101

Schneider B (2012) Climate model simulation visualization from a visual studies perspective. WIREs Clim Chang 3:185–193

Semenza JC, Ploubidis GB, George LA (2011) Climate change and climate variability: Personal motivation for adaptation and mitigation. Environ Health 10:1–12

Sheppard SRJ (2012) Visualizing Climate Change. A Guide to Visual Communication of Climate Change and Developing Local Solutions. Routledge, London

Sheppard SRJ, Shaw A, Flanders D, Burch S, Wiek A, Carmichael J.,… Cohen S (2011) Future visioning of local climate change: A framework for community engagement and planning with scenarios and visualisation. Futures 43(4):400–412

Skolverket (2013) Curriculum for the upper secondary school. http://www.skolverket.se/publikationer?id=2975

Spence A, Pidgeon NF (2010) Framing and communicating climate change: The effects of distance and outcome frame manipulations. Glob Environ Chang 20:656–667

Whitmarsh L, Lorenzoni I (2010) Behaviour, perceptions, and communication of climate change. WIREs Clim Chang 1:158–161

Whitmarsh L, O'Neill S, Lorenzoni I (2013) Public engagement with climate change: what do we know and where do we go from hhere? Int J Media Cult Polit 9(1):7–25

Wibeck V (2014a) Social representations of climate change in Swedish lay focus groups: local or distant, gradual or catastrophic? Public Underst Sci 23:204–219

Wibeck V (2014b) Enhancing learning, communication and public engagement about climate change – some lessons from recent literature. Environ Educ Res 20(3):387–411

Wibeck V, Öberg G, Abrandt-Dahlgren M (2007) Learning in focus groups: an analytical dimension for enhancing focus group research. Qual Res 7:249–262

Wibeck V, Neset T-S, Linnér B-O (2013) Communicating climate change through ICT-based visualization: towards an analytical framework. Sustainability 5:4760–4777

Wolf J, Moser S (2011) Individual understandings, perceptions, and engagement with climate change: insights from in-depth studies across the world. WIREs Clim Chang 2:547–569