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A systematic literature review and an integrative model

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Interactive and participatory media for public engagement with climate change: A systematic literature review and an integrative model

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Abstract

Public engagement with climate change is crucial for the success of policies and actions in response to climate change. Though, media have the potential to shape public opinion and attitudes towards climate change, the complexity of the issue and the psychology of human behaviour make the mere information and communication be ineffective in such endeavour. Thus, interactive and participatory approaches to communication promise better individual and public reception. This paper systematically reviews the empirical literature on interactive and participatory media for climate change engagement to examine and synthesize the effects of interactive and participatory media on cognitive, emotional, and behavioural engagement, and the existing challenges. A research agenda to fill the gaps in the area of interactive and participatory media is proposed and an integrative model of how media can engage the individual and public with climate change is introduced. The research in this area is multi-, inter- and trans-disciplinary and there are also many fields of practice that are involved: media and communication, information systems, visualization and computer science, environmental technology, education. To progress steadily with engaging the public with climate change, researchers and practitioners in the relevant fields should address the existing challenges and gaps. The model of public engagement proposed in the paper could furnish interested stakeholders with a reflective and practical device in this respect. One crucial objective for the future is to empower the individuals and the public as collective entity to act with knowledge, skills, and responsibility towards a sustainable world.

Keywords: public engagement, media and communication, climate change communication, climate and science communication, participation, participatory, interactive media, model, research agenda.

Highlights

- Interactive and participatory communication approaches are reviewed and evaluated with respect to public engagement with climate change.
- The literature review covered publications that appeared until December 2018 and which were selected based on a systematic search protocol.
- Sixteen empirical studies and four literature reviews have been retrieved for analysis.
- The studies covered both developed and developing countries and the review identified commonalities and challenges for each group.
- The studies covered three main forms of communication, namely news media, arts, and information technology.
- The review identified a set of propositions indicating the effectiveness of the interactive and participatory media features and a set of challenges.
- A model for understanding the roles, the challenges, and opportunities that media have in climate change engagement is proposed.
- The model distinguishes between individual and public levels of analysis and four stages of reaching engagement.
- Implications and future research agenda are discussed.

List of abbreviations

3D – Three dimensional

CC – Climate change

GIS – Geographic information system

ICT – Information and Communication Technology

IPCC – Intergovernmental Panel on Climate Change

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1 Introduction

Scientists have reached the consensus that climate change is one of the most challenging global issues of current era and that there is an urgent need to act to overcome the social and environmental impact of climate change (IPCC, 2018). For successful implementation of actions responding to climate change, the public understanding of and engagement with climate are crucial (Howe et al., 2015). However, the problem of engaging the public with such a complex issue as climate change is not easy (Moser, 2011). Even where climate change awareness and concern levels are high, the behavioural change towards adaptation or mitigation is difficult to attain (see e.g., Wei et al., 2014; Taylor et al., 2018). The explanation is that behaviour is driven strongly by many other factors besides knowledge and information, such as social influence, habits, and values (Moser, 2011). Moreover, barriers in reaching engagement have been identified as being related to the media characteristics, the cognitive and psychological aspects of information processing, the complexity of the topic itself and the politicization of the topic (Moser & Dilling, 2011).

In this paper, the focus is on media characteristics, their interactivity and participatory affordances. The goal is to understand how digital media can be better realized and utilized as to support effective communication and public engagement with climate change. Media and communication have the potential to shape the public opinions and can influence people behaviour through the better understanding of the science and importance of climate change issues and through multiple mechanisms including social influence and reflection on values, norms and habits which eventually lead to interrogating and/or changing mental models and thus, to encouraging people towards changing behaviour (Lakoff 2010; Sterman, 2011). However, empirical studies addressing this issue are sparse, despite a relatively large body of literature on climate change communication (see for reviews, Cagle & Tillery, 2015; Moser, 2010, 2016; Pearce et al., 2015; Wibeck, 2014). There are numerous conceptual and theoretical papers indicating that simple language, appropriate frames, visual representations should be used to communicate effectively climate change issues (see e.g., Lakoff, 2010; Bushell et al., 2016). Bushell et al. (2016) recommends a strategic narrative communication process through which the public and different stakeholders are inspired, empowered, and engaged towards collaborative communication and action. Similar guidelines are proposed for designing games and visualization media (Ouariachi et al., 2017; Sheppard 2005; Sheppard et al., 2008). It is thus recognized that innovative communication means, that empower the public and trigger their engagement with climate change, are necessary for moving the public towards adopting environment-conscious behaviour.

Participatory and interactive approaches to communication have been suggested as possible successful strategies to communication such as web-based projects and online community-based projects (see Cooney, 2010; Wibeck, 2014; Ballantyne, 2016). The one-way model of communication, based on information deficit model (Sturgis & Allum, 2004) increases understanding, but has limited benefits for public engagement or behaviour change; instead, dialogic approaches based on the interactive science model are more suitable for triggering behavioural engagement (Moser & Dilling, 2011; Wolf

and Moser, 2011; Wibeck, 2014). Ballantyne (2016) points also out that communication as interaction and constitutive, meaning-making approaches to communication are needed. Moreover, Sterman (2011) posits that IPCC information about climate change should be communicated to public and policy makers via interactive simulations to elicit experiential learning. However, currently the literature on climate change communication paints a quite incomplete picture, in that effectiveness of interactive and participatory media is not extensively studied or rigorously demonstrated. Thus, this paper focuses on reviewing the existing research to identify studies addressing this issue with the purpose to identify successful approaches, challenges, and gaps. To this end, this study systematically reviews the literature on public perception and communication of climate change with the following research questions in mind.

(1) *To what extent empirical research on climate change communication touches upon participatory and interactive media and what are the characteristics of this research area?*

(2) *How is engagement with climate change operationalized in the selected studies?*

(3) *What works well and what challenges exist relative to the effectiveness of these approaches in triggering engagement with climate change?*

2 Climate change

Climate change is an umbrella term denoting systematic changes over long periods, such as more than a decade, in Earth's climate (Hulme, 2017). Partly, climate change is caused by natural factors, however, there are estimations and evidence that human activity leading to an increase in greenhouse gases has a significant role in the ongoing climate change – the so-called anthropogenic climate change (Houghton et al., 2002). The climate change phenomenon has been for long studied (see Hulme, 2017; Wilson, 2000). Scientific findings provide evidence for its existence (Houghton et al., 2002) and confirm its anthropogenic nature (see e.g., Karoly et al., 2003; Stott, Stone & Allen, 2004). Given the potential risks associated with anthropogenic climate change highlighted by the scientists in the field, in 1988 the Intergovernmental Panel on Climate Change (IPCC) has been created by the United Nations Environment Programme and the World Meteorological Organization in order to assess and review the scientific knowledge about climate change, and to disseminate the findings and report on the potential environmental and socio-economic impacts (IPCC, n.d.). The IPCC work is the result of contributions from thousands of scientists to ensure their reviews on climate change knowledge are objective, accurate, and complete. The 2018's IPCC draft report (IPCC, 2018) states that the planet global warming has reached in 2017 the increase with 1°C above the temperature level of pre-industrialized era, while in many regions the temperature increased above the global average. According to this report, the recommendation is to mobilize policymakers and society to curb the temperature increase at 1.5°C above the pre-industrial level to avoid stronger and more negative impacts on the Earth's natural ecosystem. Two types of strategies are described as response to climate change: adaptation and mitigation (IPCC, 2018). Adaptation refers to taking actions to reduce the negative impacts of climate change and to exploit any potential positive effects.

Mitigation refers to taking actions to reduce the impact of human activity on climate by reducing greenhouse gases emissions and aims at limiting the increase of global temperature to 1.5°C above the pre-industrial era (IPCC, 2018).

Historically, the concept of climate change evolved from solely a technical description of climatic changes in the 1960s to encompass an issue of humankind in the 1970s to the present days where global climate change becomes a "new condition through which human life now takes shape" (Hulme, 2017 p. 6). The term global climate change appeared in the 1960's to point out the global impact on climate that human activity has through carbon dioxide emissions and pollution (Hulme, 2017). Besides its scientific and technical relevance (Wilson, 2000), the climate change topic is pervasive to our lives and has economic, social, psychological, political and cultural dimensions (UNFCCC, 1992; Bushell et al., 2016; Hulme, 2017). Climate change is considered as being one of the most complex issues of our times (Wilson, 2000).

The term climate change is often used in media interchangeably with global warming (Leiserowitz et al., 2014); however, the latter has a more precise meaning. Namely, global warming denotes the increase in Earth's surface average temperature caused by the greenhouse gases emissions from human activity. On the other hand, climate change encompasses the global warming, but also other changes in climate that have anthropogenic nature (Hulme, 2017). These changes include extreme precipitation phenomena, changes in rainfall patterns, sea-level rise, extreme heat waves, extreme cold waves (see e.g., Houghton et al., 2002). Climate change is also associated with extreme events such as tornadoes, storms, flooding, prolonged heat waves, which might endanger human life and health, economy, and society (Forzieri et al., 2017). Moreover, climate change has adverse effects on short- and medium-term weather predictability, as extreme events are difficult to predict due to rare occurrence (Palmer & Räisänen, 2002).

In the long-term, climate change models predict a constant increase in the global temperature due to the greenhouse gases resulting from human activity (Palmer & Räisänen, 2002). According to estimations, this increase may trigger natural phenomena that could affect the environment and have adverse effects on the natural ecosystems and humankind (UNFCCC, 1992; National Research Council, 2010). The concern about global climate change especially refers to the urgency to act: the rapid evolution of anthropogenic climate change, due to the unprecedented production rate of greenhouse gases, makes difficult to impossible for the natural ecosystem to adapt (Wilson, 2000). Thus, climate change is a major global threat and challenge to human health and life (Forzieri et al., 2017; Watts et al., 2017) and requires a synchronization of actions at all levels of society to prevent and combat it (Howe et al., 2015).

3 Media and public engagement

The term “media” refers to means of conveying and communicating information (Schäfer and Schlichting, 2014; McQuail, 2005). There are various kinds of media such as film, print, and photography. Media can be classified based on the mode of presentation of information (e.g., text, visual, auditory), channels of information dissemination (e.g., radio, television, print, Internet), symbol systems (e.g., language, sounds and music, numbers, pictures). Moreover, media are characterized by the social setting and situations where media are used such as home, theatre, classroom, public space, individual experience or social experience (Salomon, 1994). When media are used to address to a large, heterogeneous, and widely dispersed audience (Janowitz, 1968; McQuail & Windahl, 1981), we refer to "mass media" such as newspapers, books, broadcast radio and television, film, recorded music, as well as online media (McQuail, 2005). Often, the term “mass media” is shortly referred to as “media”, for example in studies of media coverage of a certain topic (see e.g., Brüggemann & Engesser, 2017; Gavin et al., 2011).

Moreover, media are conceptualized also as: *meaning carriers* (see McQuail, 2005), *tools for meaning making* (Ballantyne, 2016; Jewitt et al., 2001; Pearce et al., 2015; Salomon, 1994; Kress, 2010), and *tools for experiential learning* (see Hawtrey, 2007; Kolb et al., 2000; Tyler & Guth, 1999). Ideally, media should evoke to the user an experience like that of exploration, discovery, and sense-making through which meaningful information takes shape (Olson, 1974; Salomon, 1994). Thus, the aim of media is not only *to deliver information and facilitate knowledge acquisition*, but also *to enable mental, emotional, and behavioural responses*, that is, to enable *skill cultivation or cultivation of "tools of thought"* (Salomon, 1994, p. 87), as well as *decision making* (Cooney, 2010).

Potter (2013) distinguishes between media research and mass media research. Accordingly, media research is viewed as being concerned with the full range of channels of information dissemination and all the possible ways they can be used and can affect individuals and society. In contrast, "mass media" research is viewed as being focused specifically on how people choose certain media and messages of the full range of media and messages available, how they process meaning from those messages, and how those messages shape their knowledge structures, attitudes, beliefs, emotional reactions, and behavioural patterns over time (Potter, 2013).

In this paper, the term “media” is used as in “media research” (Potter, 2013), namely, it addresses the full range of media channels, formats, and messages, and not particularly focusing on how people choose certain media and messages within their everyday life contexts (Potter, 2013). Thus, media are seen in their broadest meaning, that of means of conveying information with the purpose to communicate it to others, to make sense of the information, learn, cultivate skills, make decisions, and, in particular, to shape climate change engagement (see Ballantyne, 2016; Cooney, 2010; Hawtrey, 2007; Jewitt et al., 2001; Kolb et al., 2000; Kress, 2010; McQuail, 2005; Olson, 1974; Pearce et al., 2015; Salomon, 1994; Schäfer and Schlichting, 2014; Tyler & Guth, 1999).

Regarding climate change communication, it has been argued that in order for communication to be effective in triggering engagement, media content should be interactive, use experiential scenarios, enable participation (see e.g., Ballantyne, 2016;

Pearce et al., 2015). This approach is referred to as *the two-way communication model* that enables interactive, collaborative, and participatory communication among different public actors (see Ballantyne, 2016; Cooney, 2010; Wibeck, 2014; Wolf and Moser, 2011).

Engagement is viewed as being a three-dimensional concept involving cognitive, emotional, and behavioural responses towards a specific issue, in this case climate change (Lorenzoni et al., 2007; Moser, 2011; Moser & Dilling, 2011; Wibeck, 2014). Thus, engagement with climate change generally means that people perceive and understand the climate change issue, they experience an emotional response such as interest, concern, or worry, fear, hope, and they adopt actively appropriate climate-relevant behaviours and engage in political actions (Moser & Dilling, 2011; Wibeck, 2014). Engagement and adopting a new behaviour are influenced by the subjective interpretation and social construction of the meaning of scientific findings rather than by the information transmitted (Moser and Dilling, 2011).

A related concept is *public engagement*, also referred to as public participation, civic engagement, citizen involvement, or citizen consultation (Shipley & Utz, 2012) in all areas of society including science, environment, technology, and risk (Chilvers, 2008). Public engagement is a concept with roots in *deliberative democracy* (see Chambers, 2003; cf. Mohseni, 2020) and in the "right to the city" concept introduced by Henri Lefebvre in 1968 (see Lefebvre, 1968; cf. Purcell, 2002). Accordingly, public engagement or public participation concept maintains that citizens, inhabitants and public in general must have a central and direct role in the decision making regarding the public spaces, local communities, and society.

In the climate change communication research, public engagement ultimately aims to involve citizens into decision making as well as into contributing to, adopting, and producing pro-environment policies and actions.

4 Review method

The aim of this systematic literature review was to obtain an overview of research addressing participatory and interactive media in the context of climate change communication and public engagement. Secondary to this aim was to identify areas of future research and to integrate the review results into a theoretical framework to advance the understanding of the mechanism shaping the public engagement with climate change and the place interactive and participatory media have in this mechanism.

On one hand, this is a *descriptive literature review* (King & He, 2005) providing an *overview* and *critical analysis* (Torraco, 2005) of current research and findings. On the other hand, the review is an *integrative synthesis* (Torraco, 2005) proposing a holistic interpretation and conceptualization of the emerging topic of climate change communication and engagement. To this end, an *integrative model* that describes the mechanism of public engagement with climate change through media is proposed along with a *research agenda*.

4.1 Search protocol

The systematic search and review generally followed the comprehensive guidelines by Aveyard (2014). The review method was also applied according to various methodological papers (Kitchenham 2004; Okoli, 2015; Torraco, 2005; Webster & Watson, 2002), and practical insights from exemplary studies (e.g., Cant & Cooper, 2010; Hamari & Keronen, 2017a,b; Ghanbari et al., 2018).

The review started with initial explorations into the topic by reading various papers using a non-systematic approach (convenience sampling of relevant articles and snowball sampling using reference lists). At this stage, the research aim, research purpose and research questions were formulated. In the next step, a review protocol was defined. This protocol included the search phrase, search databases, inclusion, exclusion, and quality criteria, data extraction strategy and synthesis plan. The final search protocol was the result of many iterations. The strategy employed in the search protocol was to identify articles addressing *communication of climate change using interactive and/or participatory approaches*, and to analyse these articles as to the *effectiveness of the communication approaches for engagement, including attitudes and shaping opinions*. Thus, engagement per se was *a criterion for inclusion. Engagement was used in the review as a lens to examine the nature of people involvement with climate change in the context of media and communication.*

The search protocol yielded 955 unique papers (after removing the duplicates). First, the titles and abstracts of these articles were screened using the inclusion and exclusion criteria. At this step, papers that addressed the topic of interactive, participatory and collaborative communication/media approaches were identified as relevant and retained for further scrutiny. Second, the full text of selected articles was read and evaluated with respect to inclusion and exclusion criteria. Moreover, when inspecting the full text, a quality appraisal was conducted to assess the strength of evidence in empirical studies and the relevance of literature reviews. The selected papers were analysed, relevant information was extracted, and the results synthesized. Figure 1 shows an overview of the process of selecting and reviewing the primary studies.

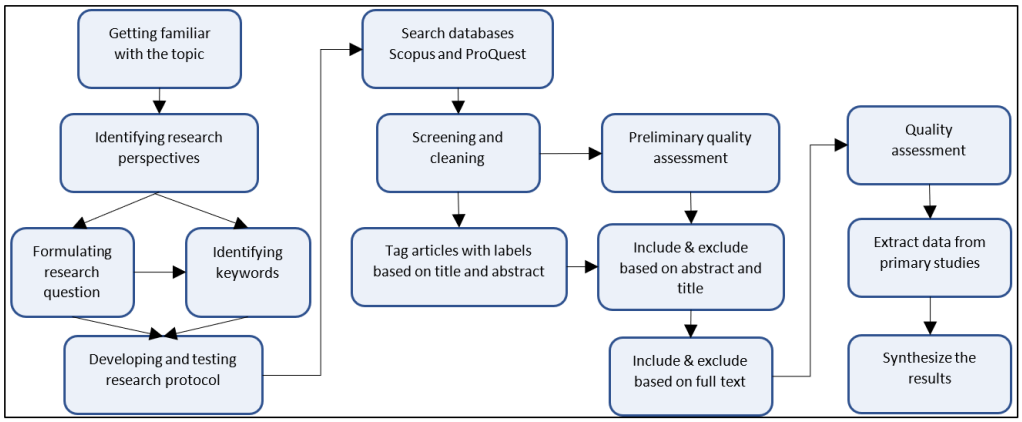

Figure 1. Stages and steps in conducting the systematic literature review

4.1.1 Search phrase

The search phrase was composed from two categories of keywords, (1) climate-change related and (2) communication(/opinion/perception/attitude) related, respectively, using a Boolean search string. Furthermore, two search phrases (Figure 2) have been defined and two separate searches were conducted whose results were aggregated. The first phrase was defined to include all relevant studies focused on *communication, media, public perception, opinion and attitude, and climate change*. The second phrase was defined to retrieve articles with the same scope as the first phrase, but which specifically addressed concepts such as *interactivity, participation, or collaboration*.

Primary search phrase

("climate change" OR "global warming" OR "extreme weather" OR "extreme climate" OR "extreme event") AND (news* OR media OR communicat* OR "public perception" OR perception OR "public opinion" OR "public attitude")

Secondary search phrase

("climate change" OR "global warming" OR "extreme weather" OR "extreme climate" OR "extreme event") AND (news* OR media OR communicat* OR "public perception" OR perception OR "public opinion" OR "public attitude") AND (interact* OR collab* OR participat*)

Figure 2. Search phrases

4.1.2 Search databases

For the search, two major databases were selected: Scopus and ProQuest. Both gave the highest and second highest number of hits in a preliminary, initial search. The search scope consisted of Title AND Keywords AND Abstract. In addition, filters for language (English), document type (research articles, review articles, literature reviews, working papers, articles in press, pre-prints) and source type (journals) were defined. For the first phrase, a second round of searching was performed by limiting the scope to Title AND Abstract to include also articles without list of keywords or subject headings. Moreover, the search phrase targeted specifically to interactive and participatory media was employed only at the field Abstract in order to retrieve as many articles as possible.

4.1.3 Inclusion and exclusion criteria

The inclusion and exclusion criteria (Table 1) were defined to assess the suitability and relevance of an article for the review. Some of these were directly relevant for answering the research questions, and some of them were related to the accessibility of the articles and data (e.g., language, availability for download online or through interlibrary loan). Moreover, a third category was related to the quality of the study as reflected by the type of publication. Given the high number of hits in the initial search, a decision was made to focus only on journal articles as they are typically more detailed, and thus, more suitable for providing the answers to the research questions. Other authors have also used this strategy of focusing only on journal articles (see Häyrinen et al., 2008).

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
• Written in English. • Peer-reviewed journal paper. • Any year of publication. • Abstract available. • Empirical studies or literature reviews. • Articles addressed to some extent the research question regarding the interactivity of media or participatory media/communication approaches. • Focus of article was on one of the following: public attitudes, public perception of climate change as a public issue, individual/public action and engagement towards climate change, issues of communication of climate change in media, mediated communication of climate change.	• Full paper was not available online or through library loan or request. • The study did not address mediated communication. The paper did not focus on the public, but on other actors such as media or policymakers or climate experts or knowledge contributors. • The study did not address interactive, collaborative, or participatory approaches or media. • The study did not address media or communication effects to any extent. • The study was related to media, but without including the human responses (i.e., climate change perceptions, attitudes, engagement). For example, it discussed framing or media coverage from analytical point of view without implications to public engagement (e.g., attitudes, perception, action support, action taking). • Quality criteria were not fulfilled.

4.1.4 Quality appraisal

Quality or critical appraisal is performed to assess which papers will be excluded for insufficient quality (Okoli, 2015) and/or for lack of relevance to the research questions (Aveyard, 2014). It assesses the strengths and weaknesses of each paper as to the strength of support or evidence in answering the review research questions (Aveyard, 2014). Issues such as data collection, interventions, analysis, results and conclusions are screened (Fink, 2013) as to their relevance to the research aim of the review (Aveyard, 2014). For this review, the focus was on identifying the studies that addressed the media interactivity or participation approaches, and how these approaches affected the engagement with climate change. Thus, the primary studies have been examined for evidence that supports drawing insights on how communication media affects engagement with climate change.

A *preliminary quality assessment* was conducted when inspecting the abstracts and tagging the articles. As a result, a few articles were labelled as not relevant if the journal was not ranked in the Finnish ranking system (http://www.julkaisufoorumi.fi/), the paper was not available online, and the results described in the abstract were not clearly related to the research topic of the review. This type of evaluation was part of the practical screen (Okoli, 2015) and was performed for pragmatic reasons as it was not possible to search and review all articles (see also Fink, 2013).

During the full-text inspection, papers considered relevant were screened for quality appraisal. *Quality assessment* was done by examining the research method employed and strength of evidence in support of answering the review research questions (see Aveyard, 2014; Kitchenham, 2004; Okoli, 2015). Okoli (2015) recommended using flexible appraisal criteria especially when the research area is new and emerging. Because, at this

stage, the number of retained articles was manageable and no redundant information was encountered, most studies found relevant were included. Thus, even where research methods or results were not very detailed, if there was presented some form of evidence of the media effects, the study was included in the review. However, critical quality or relevance issues such as that no clear results were reported, no research methods were described, or that data were not possible to identify, were reasons to eliminate some studies from review. For the quality appraisal, a hierarchy of evidence (Aveyard, 2014) was constructed to help evaluate the strength of evidence presented in each primary study.

4.1.5 Hierarchy of evidence

For this review, the studies that showed effects of media on engagement were highly valued. The best evidence could be gathered from literature synthesis studies, especially meta-analyses (Aveyard, 2014; Kitchenham, 2004). Meta analyses and systematic literature reviews can be conducted on experiments or surveys, and the later also on qualitative studies. For this review, surveys would not provide the strongest evidence (see also Potter, 2013), due to the nature of the research question which ideally requires some form of intervention or observation on how media is experienced by research participants. Thus, experiments and observation studies are more valuable. Also, longitudinal studies showing that an effect took place after an intervention are more valuable than surveys. Systematic reviews of qualitative empirical studies and narrative reviews would provide the least strength of evidence in this hierarchy because the findings highlight ideas not strongly supported by evidence. Thus, the hierarchy of evidence for this study along a categorization into levels of strength is presented in Table 2.

Table 2. Hierarchy of evidence and strength of evidence for the current literature review

Hierarchy of evidence	**Strength of evidence**	
• Meta-analyses and systematic reviews of controlled experiments, quantitative • Meta-analyses and systematic reviews of observational studies (case studies), quantitative • Meta-analyses and systematic reviews of surveys, quantitative	Very high	5
• Longitudinal studies of effects, quantitative • Controlled experiments, quantitative	High	4
• Observational studies after an intervention (case studies, including text mining), quantitative • Surveys, quantitative • Qualitative studies and systematic reviews of them (cases studies, focus groups, interviews, etc.)	Medium	3
• Narrative reviews of literature	Low	2
• Reflections and expert opinions	Very low	1

Studies using mixed-methods approaches combining quantitative and qualitative approaches (Creswell & Creswell, 2017) or studies combining design science research

(March and Smith, 1995) with quantitative and/or qualitative approaches were ranked according to their strongest level of evidence. For example, if a study used design science to create an interactive system for climate change communication and the system was evaluated in a control experiment, then this study was placed at level 5 (high) in the above hierarchy which corresponds to the control experiments.

4.2 Search outcome

The search was performed on 27 September 2018 with a follow-up search on 11 December 2018. Figure 3 presents the aggregated search and selection process outcome. The selection of articles used a staged process (Torraco, 2005). First, the articles' abstracts were screened based on the inclusion and exclusion criteria. As a result, 37 articles were found relevant based on title and abstract inspection. During the full-text screening process, 13 more papers were added for full-length inspection based on cross-reference and manual search. Thus, 50 papers were screened in full, of which 16 empirical studies were found relevant for in-depth review by complying with the inclusion and exclusion criteria. In addition, 4 literature reviews on games, visualization, and online communication were identified and included in the review and systematically examined.

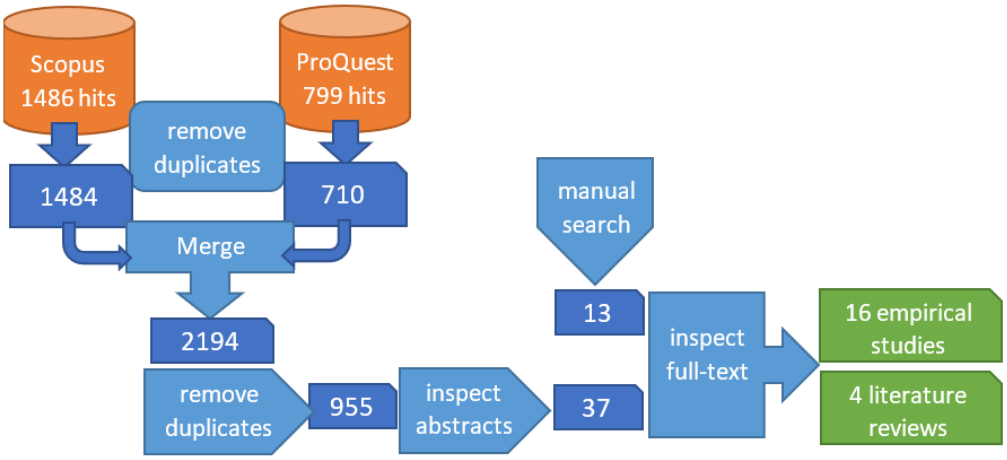

Figure 3. Flow chart representing the selection of primary studies

4.3 Data extraction

For the data extraction, it was used a form with questions asking about the type of media, use context, type of interactivity, type of participation, and the engagement dimensions discussed, as well as research methods (Table 3). The information extracted was organized in a table, with articles on the rows and the items extracted on the columns. Most of the information was found in the method, results, or discussion sections. In addition to the core issues in Table 3 (media and engagement dimensions), the study characteristics were scrutinized to assess to what extent the results are comparable and generalizable, as well as to identify gaps and future work. These issues were related to the employed research methods and designs and to the strength of evidence. These latter issues provided the basis for quality assessment (Aveyard, 2014; Kitchenham, 2004).

4.4 Synthesis

The findings are summarized in both author-centric and concept-centric manner according to Webster & Watson (2002) guidelines. In the author-centric approach, the studies are summarized individually by highlighting the relevant dimensions extracted for answering the research questions. In the concept-centric approach, the studies are summarized by central themes and concepts that span across multiple articles which are relevant for answering the research questions (Webster & Watson, 2002).

Table 3. Data extraction form

Category	Data extracted
Media dimensions	
Media of communication	Type of communication, type of media technology
Engagement dimensions	
Cognitive responses	Awareness, perception, knowledge, attention, cognitive load, risk perception
Emotional responses	Concern, worry, fear, hope
Behavioural responses	Decision making, action support, action taking, political engagement
Study characteristics	
Context of the study	Country where the data was collected
	Type of public: farmers, students, locals, professionals, etc.
	Year of data collection
	Adaptation or mitigation orientation
Research methods	Aim of study
	Research method: Empirical quantitative (e.g., survey, experiment, case study)
	Research method: Empirical qualitative (e.g., case study, interview, focus groups)
	Research method: Design Science Research, construction and evaluation of an artefact
	Number of participants in empirical studies
	Data collection
	Data analysis
	Results
Publication	Authors
	Publication year
	Language
	Journal

5 Results

In total, 16 empirical studies were identified and 4 literature reviews (see Appendix). Next, the empirical studies are synthesized according to the research questions: *(1) To what extent empirical research on communication climate change touches upon participatory and interactive media and what are the characteristics of this research area? (2) How is engagement with climate change operationalized in the selected studies? (3) What works well and what challenges exist relative to the effectiveness of these approaches in triggering engagement with climate change?* The literature reviews are described separately from the empirical studies and are used to reflect on and consolidate the empirical findings at the end of the Results section.

The characteristics of the empirical studies are presented in tables using an author-centric approach (by citation) and described in the text following a concept-centric manner and accompanied by corresponding concept-matrices. The empirical studies were diverse in terms of aims, communication media, and findings.

For answering the first research question (*To what extent empirical research on communication climate change touches upon participatory and interactive media and what are the characteristics of this research area?*), the studies are summarized by different aspects such as the year of publication, country of intervention, aims, communication media, interactive and participatory approaches, type of public, and climate change response (adaptation and/or mitigation). Table 4 depicts the years of publication, country of intervention, type of public and type of response using the author-centric style. Critical analysis is provided in text accompanied by concept-centric matrices.

Table 4. Primary empirical studies by year, country, type of public, adaptation/mitigation focus and aim of study

Authors, year **Journal**	**Country**	**Type of public**	**Adaptation or mitigation**
Pereira et al., 1999 *Int'l J. of Environment and Pollution*	Italy	Lay-audience, heterogenous groups	mitigation
Khan et al., 2012 *Int'l J. of Sustainable Development and World Ecology*	India	Farmers and fishermen, local NGOs and local governmental bodies, local vendors and shop keepers, tourists and visitors	adaptation
Salathong, 2013 *Int'l J. of Media & Cultural Politics*	Thailand	Students	mitigation
Wibeck et al., 2013 *Sustainability (Switzerland)*	Sweden	Decision-makers (politicians, public and private professionals) and citizens visiting the "Swedish Politicians Week"	mitigation
Harris, 2014 *Pacific Journalism Review*	Fiji	Local communities and professionals in Pacific Islands	adaptation and mitigation
Lieske et al., 2014 *Estuarine Coastal and Shelf Science*	Canada	Public as well as participants recruited at schools, professional bodies, non-governmental, community-based organizations	adaptation

Authors, year Journal	Country	Type of public	Adaptation or mitigation
Schroth et al., 2014 *Environmental Communication*	Canada	Students and experts	adaptation and mitigation
Fernandez et al., 2015 *Climatic Change*	Bolivia	Indigenous population	adaptation
Mycoo, 2015 *Int'l J. of Climate Change Strategies and Management*	Trinidad and Tobago	Local community of adults and high-school students, indigenous	adaptation
Newell and Dale, 2015 *Environmental Communication*	Canada	Academics, climate change practitioners, policy makers (elected officials), public	adaptation and mitigation
Williams et al., 2015 *Global Environmental Change*	global	n.a.	not applicable
Chowdhury et al., 2016 *SpringerPlus*	India	Vulnerable population as trainee and actors, local community in the island and vicinity as the audience	adaptation
Jacobson et al., 2016 *Ecology and Society*	USA	Students and public visitors	adaptation and mitigation
Ndhlovu and Mpofu, 2016 *Jamba: Journal of Disaster Risk Studies*	Zimbabwe	Local farmers	adaptation
Inamara and Thomas, 2017 *Pacific Journalism Review*	Papua New Guinea	Local community in Andra Island, Manus Province	adaptation
Burke et al., 2018 *Global Environmental Change*	UK	Lay audience visiting the art exhibition (tourists and residents)	adaptation and mitigation

5.1 Years of publication and year of data collection

The empirical studies were published between 1999 and 2018 (see Figure 4). There is a visible gap in publications between 1999 and 2012[1]. Most of the studies were published between 2014-2016 (10 studies).

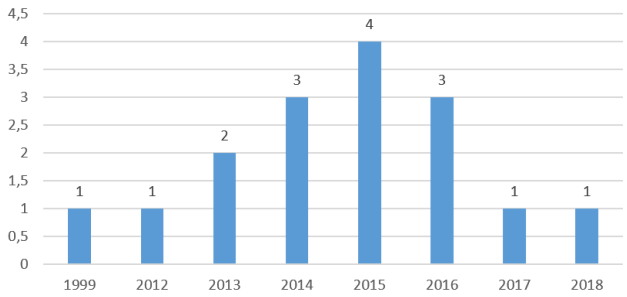

Figure 4. Distribution of empirical studies by year of publication

[1] A similar gap, matching the first decade of 2000s, is also apparent in other systematic literature reviews. For example, the review of serious games by Flood et al. (2018) identified only two studies published during the mentioned decade, in particular, two working papers published in 2006-7.

It is possible that the studies published during 2017-2018 were not yet indexed by the search engines at the time of search. When comparing the data collection year with the publication year, a general lag of 2.3 years (min 1 year, max 6 years) since the end of data collection was observed. However, 7 studies did not report the year(s) of data collection.

5.2 Countries and type of public

Studies varied with respect to the *country* of reference as follows (see Figure 5). Seven studies covered research in developed economies (Canada (3), USA (1), UK (1), Italy (1), and Sweden (1)). Eight studies covered developing economies in Asia (4), Africa (1), Latin America and the Caribbean (2), and Pacific Islands (1). One study did not focus on a specific country, and the data collection was based on Twitter posts, without analysing country of origin of the data (see Williams et al., 2015).

The *type of public* was also identified to determine the communality of the studies in terms of this contextual variable. Some studies addressed more than one category of public. The following categories were identified:

- **local-based communities or public** (e.g., Khan et al., 2012; Harris, 2014),
- **farmers & fishermen** (e.g., Khan et al., 2012),
- **indigenous populations** (e.g., Fernandez et al., 2015),
- **students** (e.g., Salathong, et al. 2013),
- **heterogeneous groups** (e.g., Perreira et al., 1999),
- **tourists or visitors** (e.g., Khan et al., 2012; Jacobson et al., 2016),
- **professionals or decision makers** (e.g., Wibeck et al., 2013; Lieske t al., 2014).

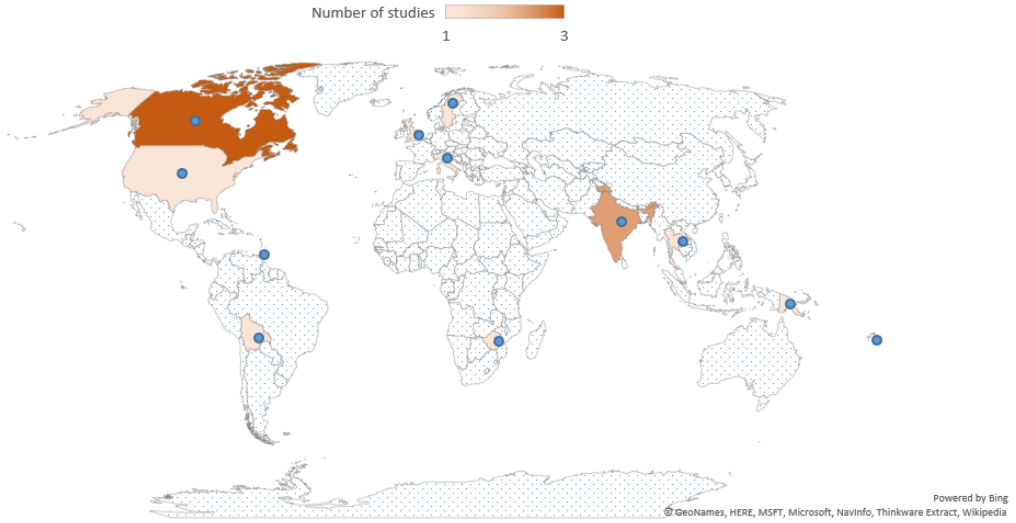

Figure 5. Distribution of empirical studies by country

5.3 Aims of studies and climate change response focus

The *aims* of the selected studies can be grouped into three main themes:

1) **design and evaluation of interactive and/or participatory communication frameworks or systems** (Khan et al., 2012; Salathong, 2013; Schroth et al., 2014; Wibeck et al., 2013);

2) **exploratory studies of various interactive and/or participatory communication media and/or technologies** (Chowdhury et al., 2016; Harris, 2014; Inamara & Thomas, 2017; Mycoo, 2015; Ndhlovu & Mpofu, 2016; Newell & Dale, 2015; Pereira et al., 1999; Williams et al., 2015); and

3) **intervention studies with quantitative evaluation** (Burke et al., 2018; Jacobson et al., 2016; Lieske et al., 2014; Fernandez et al., 2015).

Framework design and system design studies have been published in early 2010s, displaying for that period of time a trend towards conceptual research (frameworks) that was applied to system design. Exploratory studies are the most common (8) and were mainly published during 2014-7. Only 4 studies evaluated interventions using quantitative approaches (see Figure 6) and these were published during 2014-8.

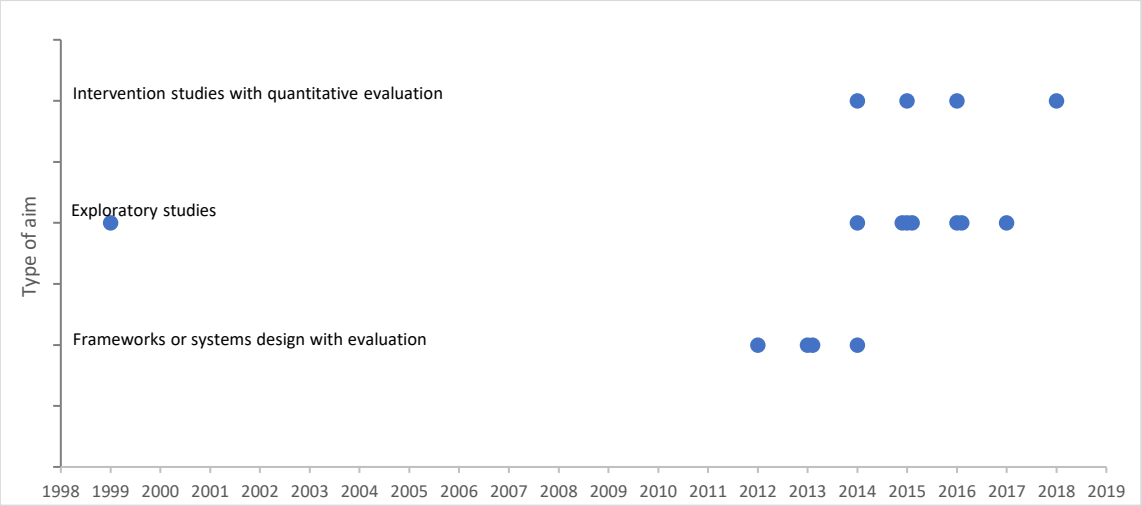

Figure 6. Aims of empirical studies by year

The last column in Table 4 indicates the framing of the study in terms of *climate change response*: adaptation and/or mitigation. This framing was not always explicitly stated in the papers (for example, Burke et al. 2018 focused generally on effective communication for increased awareness and engagement in the context of both adaptation and mitigation challenges). Three studies focused solely on mitigation, 5 studies were oriented towards both adaptation and mitigation, 7 studies focused solely on adaptation, while one study (Williams et al., 2015) was not categorized in relation to adaptation and mitigation.

Overall, the research context of the primary studies showed a high degree of heterogeneity in the empirical research. A concept matrix using cross-tabulation (Table 5) is formed based on these variables. It is seen that *local communities* are involved in the empirical research to a high degree especially when exploring the effectiveness of communication

as well as when evaluating the interventions. In developed countries, the focus is almost always on mitigation or combining mitigation with adaptation. It is observed *a shortage of intervention studies, though the most recent research indicates a trend of moving from design and evaluation studies towards exploratory and intervention approaches*.

Table 5. Overview of context in empirical studies

Aim	Countries	Years/paper	Type of public	Response
Design and evaluation 4	developed: 2	Wibeck et al., 2013	p + s	m
		Schroth et al., 2014	p + s	m + a
	developing: 2	Khan et al., 2012	p + f + l + t	a
		Salathong, 2013	s	m
Exploratory 8	developed: 2	Pereira et al., 1999	h	m
		Newell and Dale, 2015	p + h	m + a
	developing: 5	Harris, 2014	l + p + i	m + a
		Mycoo, 2015	l + s	a
		Chowdhury et al., 2016	l	a
		Ndhlovu and Mpofu, 2016	f /local	a
		Inamara and Thomas, 2017	l + i	a
	n/a: 1	Williams et al., 2015	h	n/a
Interventions 4	developed: 3	Lieske et al., 2014	h + p + l	a
		Jacobson et al., 2016	s + t	m + a
		Burke et al., 2018	t + l	m + a
	developing: 1	Fernandez et al., 2015	i	a

Abbreviations: Type of public: p = professionals or experts; s = students; f = local farmers; l = local communities; t = tourists (visitors); h = heterogenous (e.g., Twitter communities); i = indigenous or traditional communities. Response: m = mitigation, a = adaptation.

5.4 Publication forums

The empirical studies were published equally in high-ranked and lower-ranked journals. The top journals (by their impact factor) identified in this review were Global Environmental Change, Climatic Change, Ecology and Society, Sustainability, International Journal of Sustainable Development and World Ecology, and Environmental communication (Figure 7). All together these journals covered the topic of interactive and participatory media in 8 articles (half of the whole set). Some journals address more than one field. As an example, Climatic Change journal publishes research in both Environmental Science and Earth and Planetary Science. Ranking the journals by discipline (Figure 7), yielded that the most frequent fields were Environmental Science, followed by Geography, Development, and Planning in the Social Sciences, and then by Communication. A bibliographical analysis of the articles showed that the 16 articles have not shared a lot of references; the most cross-referenced article being Moser (2010) which was cited in three primary studies. Furthermore, *generally there were not found cross-references among the reviewed articles.* (Only Inamara and Thomas (2017) cited Harris (2014) in the Pacific Journalism Review journal.)

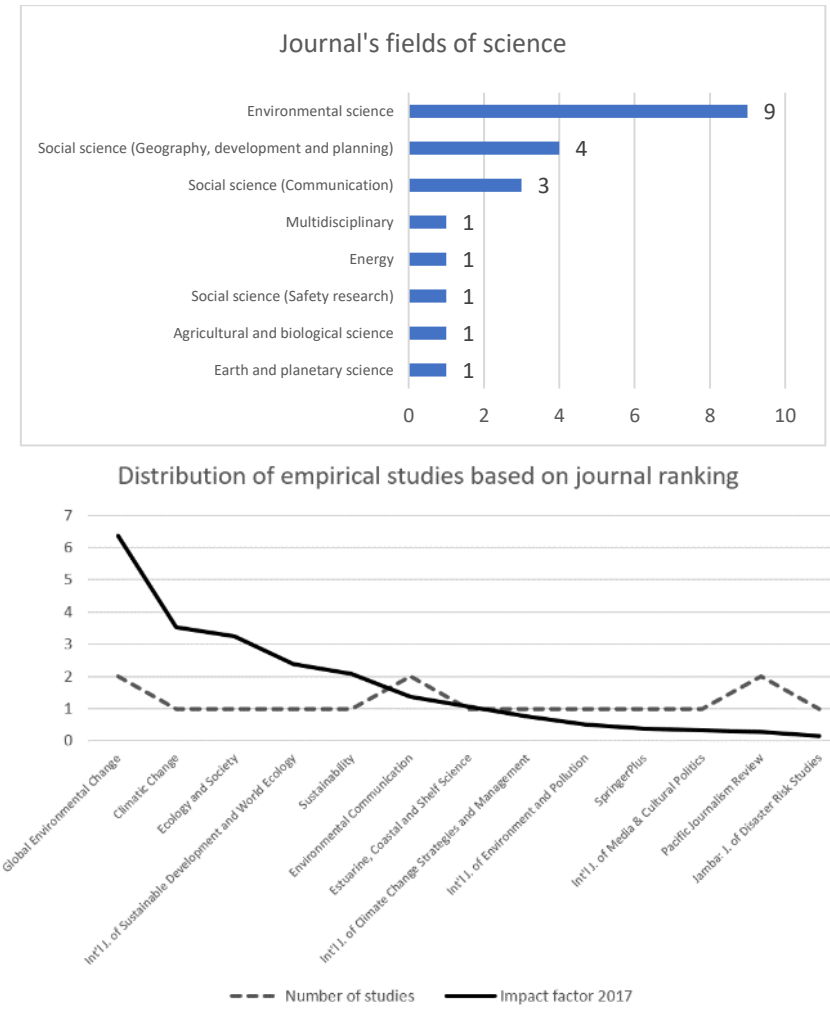

Figure 7. Publication forums: fields of science (top), journals and journal ranking based on impact factor (bottom)

5.5 Research methods

When examining the *research methods*, the analysis focused on the methods employed for studying the *public reception* of mediated communication of climate change, in other words, the methods utilized for studying the *media effects* (Table 6). Some articles evaluated multiple stakeholders such as journalists (see Salathong, 2013) or experts (see Ndhlovu and Mpofu, 2016; Salathong, 2013; Schroth et al., 2014), and some studies employed multiple methods, but not all were relevant for examining the mediated communication of climate change (see e.g., Chowdhury et al., 2015). Thus, Table 6 reports only information on *how the public responses to mediated communication of climate change were investigated* (other data such as experts' feedback on how to improve a game interface as presented by Schroth et al., 2014 were not the focus of this analysis).

Most of the studies either employed a mixed-methods research strategy combining quantitative and qualitative approaches or combined design research with quantitative and/or qualitative approaches. Furthermore, most of the studies employed the case study and focus groups strategies for collecting data from multiple sources using techniques such as survey, experiment, interviews, and content analysis of media under investigation.

Some studies did not provide details on the data analysis strategy, but when qualitative data were collected most of the reporting was based on interpretative approaches. The studies employed convenience sampling (5), purposeful sampling (4), multiple sampling procedures (3), snowball sampling (2), random or systematic sampling (2), or have not reported the type of sampling (7).

The level of analysis was individual or group, covering different populations especially residents of different professional background such as farmers and students (in 7 studies), tourists or visitors (3 studies), and students or heterogeneous groups without local background (7 studies) (see also Table 4 and Table 5). The number of study participants varied from 7 to 423 individuals, and from 5 to 14 groups. Three studies have not provided information on the number of participants, and the study using a text mining approach to analyse Twitter messages employed a sample of 1545 users.

Some of the primary studies were part of larger projects described in the same paper or elsewhere (8), while other studies focused on specific aspects as reported in this review (8) (see column 7 in Table 6).

Based on the research approach employed and reported, a strength of evidence indicator was defined according to the pre-defined hierarchy of evidence (Table 2). The studies ranged from very low evidence where the evaluation is limited to authors reflections (e.g., Khan et al., 2012) to high where evaluation is based on quantitative data obtained from examining an intervention evaluated in a controlled, experimental manner. The identified longitudinal studies evaluated an outcome variable before and after an intervention (see Fernandez et al., 2015; Jacobson et al., 2016; Schroth et al., 2014).

The concept matrix in Table 7 gives an overall perspective on the distribution of research methods in the reviewed studies. There is a serious shortage of pure quantitative studies, but the mixed methods studies combining qualitative and quantitative approaches are compensating to some extent the aforementioned scarcity. Most of the studies including quantitative approaches are in developed economies, while pure qualitative studies are predominant in developing countries. It was expected that quantitative studies provided stronger evidence of media effects on engagement, however, especially due to a low number of participants and employing surveys rather than controlled experiments, in some of the quantitative studies the effects were evaluated as being medium to weak. Furthermore, other studies employed relatively small sample sizes or involved research participants that were not representative for the target users, or the analysis relied solely on qualitative data; thus, while according to the hierarchy of evidence would have been classified as high, they only provided medium to high strength of evidence due to shortcoming in the implementation of the research method.

The summary of the research approaches indicates: *1) a trend towards mixed-method approaches*; 2) *a shortage of longitudinal and controlled experiments*; 3) *a lack of meta-analyses; and 4) a variety of approaches to sampling and study designs*.

Table 6. Research approaches in the primary studies (ordered by year of publication and name of the first author)

Article	Research approach	Data collection strategy	Data analysis strategy	Number of participants	Sampling	Larger study	Strength of evidence
Pereira et al., 1999	Qualitative case study (qualitative evaluation)	In-depth groups data collection of feedback and reports	n.a.	54 lay people (6 groups x 9 members)	n.a.	yes	medium
Khan et al., 2012	Qualitative case study (framework design, interviews)	Naturalistic approaches, but not explicitly described	n.a.	n.a	n.a	yes	very low[1]
Salathong, 2013	Qualitative	Content analysis of news and focus groups with students	n.a.	7 students	Snowball sampling	yes	low
Wibeck et al., 2013	Qualitative case study (framework design and qualitative case study)	Survey	n.a.	113 visitors	Convenience sampling	yes	low[2]
Harris, 2014	Qualitative case study	Interview, content analysis of videos	n.a.	5 teams of residents	n.a.	no	low[3]
Lieske et al., 2014	Mixed methods case study (quantitative and qualitative)	Focus groups, survey, experiment	Descriptive statistics and content, thematic analysis	157 residents (14 focus groups)	Random, purposeful, and convenience sampling	no	medium-high[4]
Schroth et al., 2014	Mixed-methods (design science, quantitative and qualitative)	Experiment, quantitative survey before and after intervention, interview	Statistical analysis of quantitative data	18 students 10 experts	Convenience and snowball sampling	yes	medium-high[5]
Fernandez et al., 2015	Quantitative case study	Longitudinal case study, experiment, survey for collecting quantitative and qualitative data	Statistical analysis of quantitative data	424 residents (74 in the experimental group)	n.a.	no	high
Mycoo, 2015	Mixed-methods case study (quantitative and qualitative)	Multi-stage case study, survey, focus group meetings, workshops; reflections based on literature	Descriptive statistical analysis of quantitative data	101 residents	n.a.	no	medium to low[6]
Newell and Dale, 2015	Mixed-methods (dissemination strategies, observation and quantitative evaluation)	Quantitative survey, online data-based metrics, interview	Statistical analysis of quantitative data	n.a.	Open participation	yes	medium to low[7]

Article	Research approach	Data collection strategy	Data analysis strategy	Number of participants	Sampling	Larger study	Strength of evidence
Williams et al., 2015	Mixed methods (quantitative and qualitative)	Twitter messages	Text mining, network analysis, and manual labelling of qualitative data (Twitter messages)	1545 Twitter users	Based on criteria set for active users	no	medium to high
Chowdhury et al., 2016	Qualitative	Survey	n.a.	n.a.	Purposeful sampling	yes	low to very low[1]
Jacobson et al., 2016	Mixed-method case study (qualitative and quantitative)	Field trip, group discussions, co-creation of artefact, evaluation, pre-and-post trip survey, assessment by experts	Statistical analysis of quantitative data	18 students	n.a.	no	medium to low[5]
Ndhlovu and Mpofu, 2016	Mixed methods case study (quantitative and qualitative)	Survey, naturalistic participant observation, in-depth interview	Statistical analysis of quantitative data, thematic analysis, and pattern matching	236 farmer residents	Households' simple random sampling, purposeful and systematic sampling	yes	medium
Inamara and Thomas, 2017	Qualitative case study (qualitative, participatory action research)	Focus group discussions, interviews, naturalistic approaches, community feedback sessions	Interpretative approaches	13 residents	n.a.	no	low
Burke et al., 2018	Mixed method case study (quantitative and qualitative)	Survey, interviews, and Q method, artwork-based intervention	Statistical analysis, clustering of Q method statement	15 tourists and residents	Convenience sampling	no	medium to low[5]

Notes: 1. no data identified; 2. no data analysis, only indicative findings; 3. difficult to identify data; 4. some results rely only on qualitative data (in Lieske et al., 2014); 5. the sample size is small, and sample is not representative; 6. survey results are reliable (data represents 69% of total population), but for focus groups and workshops it is difficult to identify the data; 7. no systematic observations.

Table 7. Overview of research methods in empirical studies

Research method	Countries	Years/paper	Type of public	Response	Evidence
Mixed methods (quantitative and qualitative) 8	developed: 5	Lieske et al., 2014	h + p + l	a	M->H
		Schroth et al., 2014	p + s	m + a	M->H
		Newell and Dale, 2015	p + h	m + a	M->L
		Jacobson et al., 2016	s + t	m + a	M->L
		Burke et al., 2018	t + l	m + a	M->L
	n/a:1	Williams et al., 2015	h	n/a	M->H
	developing: 2	Mycoo, 2015	l + s	a	M->L
		Ndhlovu and Mpofu, 2016	f	a	M
Qualitative 7	developed: 2	Pereira et al., 1999	h	m	M
		Wibeck et al., 2013	p + s	m	L
	developing: 6	Khan et al., 2012	p + f + l + t	a	VL
		Salathong, 2013	s	m	L
		Harris, 2014	l + p + i	m + a	L
		Chowdhury et al., 2016	l	a	L-> VL
		Inamara and Thomas, 2017	l + i	a	L
		Ndhlovu and Mpofu, 2016	f	a	M
Quantitative 1	developing: 1	Fernandez et al., 2015	i	a	H

Abbreviations: Type of public: p = professionals or experts; s = students; f = local farmers; l = local communities; t = tourists (visitors); h = heterogenous (e.g., Twitter communities); i = indigenous or traditional communities. Response: m = mitigation, a = adaptation. Evidence: ** VL = Very Low, L = Low, M = Medium, H = High, L->VL = Low to Very Low, , M->L = Medium to Low, M->H = Medium to High.

5.6 Communication approaches

The topic of climate change was novel to the target communities, and many studies included a training stage; thus, to accommodate the communication process, focus groups meetings, training workshops, field trips were organized. There were however, a number of studies where the mediated communication or media consumption was studied in its natural course without organized training or workshops, or it was examined in an experimental setting (see Lieske et al., 2014; Ndhlovu & Mpofu, 2016; Newell & Dale, 2014; Schroth et al., 2014; Wibeck et al., 2013; Williams et al., 2015). Three categories of communication approaches have been identified across the studies: news media, information and communication technology (ICT)-based, and arts.

News media were marginally represented in the reviewed articles; only 4 articles addressed to some extent news media such as newspaper, radio, broadcast (Khan et al., 2012; Salathong, 2013; Fernandez et al., 2015; Ndhlovu & Mpofu, 2016). In this group, one article focused on how climate change is depicted in the newspapers and to what extent the media representation affects the public response (Salathong, 2013). Khan et al. integrated the news media in a framework for communicating climate change. Fernandez et al. communicated climate change through a participatory workshop where the presentation emulated the representation of climate change in news media. Finally, Ndhlovu and Mpofu reported the usage patterns and preferences of different news media channels in a farmers' community. All these studies addressed developing economies and vulnerable communities (India, Thailand, Bolivia, and Zimbabwe).

Information and communication technology (ICT)-based media were addressed in various social contexts in 9 articles: 6 in developed and 3 in developing countries. The 6 studies in the developed economies examined the use of simulation models (Pereira et al., 1999; Italy), visualizations (Wibeck et al., 2013; Lieske et al., 2014; Sweden and Canada, respectively), online and social media (Newell & Dale, 2015; Williams et al., 2015; Canada and n/a, respectively), and games (Schroth et al., 2014; Canada). In the category of online and social media studies, Williams et al. (2015) studied Twitter messages about climate change to observe social networks and communications patterns, and Newell and Dale (2015) studied the effect of various online information channels (blogs, chats) on audience engagement. The study by Williams et al. did not focus on a certain country, however the research context implies a relatively advanced sociotechnical environment characterized by computer literacy and internet connection.

Only one study that addressed the use of games for communicating climate change to public was included in the review that fulfilled the inclusion criteria[2] regarding public perception, interactivity, and participatory approaches (see Schroth et al., 2014). Schroth et al.'s game featured 3D visualization and simulation models and was evaluated on a student sample as well as with experts to provide further improvement suggestions as to how to increase usability and engagement. Similarly, only two studies addressing visualization as a mode of communicating climate change issues were included based on fulfilling the inclusion criteria[3]. In this group, Wibeck et al. (2013) focused on a visualization approach that used a digital dome theatre which integrated an immersive learning environment with capacity of 100 visitors. On the other hand, Liseke et al. (2014) evaluated the effectiveness of a 3D visualization in the form of a video clip and of a web-based geographic information system (GIS) map.

Three studies approached the ICT-based communication of climate change in *rural and/or indigenous communities*. In this category, Ndhlovu and Mpofu (2016) examined the extent of use of online media and mobile phones for climate change communication through a survey in Zimbabwe. On the other hand, Mycoo (2015) reported on the experience of exploring modern media technologies such as a GIS and online training materials in training workshops in an indigenous community in Trinidad and Tobago. Moreover, Fernandez et al. (2015) addressed the use of interactive media within workshops settings with indigenous population in Bolivia with the purpose to study the influence of communication on climate change awareness.

[2] The literature review by Flood et al. (2018) focused specifically on games, in particular serious games, but the articles included focused solely on adaptation behaviour, and specific stakeholders and their learning and decision-making processes (rather than the public).

[3] More studies focusing on visualization of climate change were identified, but these did not fulfil all inclusion criteria such as analysing the public attitude and engagement and describing participatory/interactive communication approaches.

Table 8. Communication approach, media technology, and engagement dimensions

Article	Communication approach	Media technology	Cognitive engagement	Emotional engagement	Behavioural engagement
Pereira et al., 1999	Interactive ICT-based models of integrative assessment of climate change	digital	awareness, understanding, reflection on own lifestyle and on environment	suspicion and rejection reactions caused by lack of credibility of models	mitigation responses in terms of sustainable activities and responsibilities (willingness of acting, "what can I do" questions)
Khan et al., 2012	A mixed strategy for communication including radio, newspapers, and two-way communication	multiple media (radio, print, street plays, workshops, etc.)	awareness and understanding of risks, vulnerabilities, and climate change issues, perception of CCs such as sea level rise, information acquisition	feel the threat of sea level rise	build and practice skills, capacity building, action taking, decision making, design adaptation projects
Salathong, 2013	Newspapers and newspaper articles on climate change	digital archive	awareness, understanding, knowledge of impacts and solutions	appeal, alertness, empathy, scare, closeness to home	practical problem-solving skills (e.g., do not use plastic bags), willingness to act and take actions
Wibeck et al., 2013	Geo Dome ICT-based interactive visualization of climate change.	digital visualization mixed with verbal presentation	perception, understanding, knowledge, interpretation and sense-making of CC	interest, relevance	decision making
Harris, 2014	Participatory video (making)	digital and video tape-based videos	awareness and knowledge about impact of CC and adaption needs	not addressed	skills of transferring knowledge about CC through participatory video, disseminate knowledge about CC to communities, capacity building, economic empowerment of women, community involvement and representation, building resilience in the community
Lieske et al., 2014	Power point presentation with verbal live commentary, 3D visualization as a video clip, a web-based interactive tool as a GIS map	multiple media: digital (3D animations, movie clip, GIS), verbal presentation, images, paper map	risk awareness and perception	concern, emotional engagement, "shock"	dissemination or raising awareness, desire for political and social involvement, action taking – adaptation intentions of moving to another place

Article	Communication approach	Media technology	Cognitive engagement	Emotional engagement	Behavioural engagement
Schroth et al., 2014	Interactive educational game featuring 3D visualizations and simulations for climate change adaptation and mitigation	digital game, 3D visualization included	awareness and perception of CC impact, learning, understanding, sense (belief) of responsibility, knowledge about effects, thought provoking	concern, urgency, attitudes	in-game mitigation and adaptation actions, in-game active decision making, responsibility and intention to change the behaviour
Fernandez et al., 2015	Audio-video interactive presentations emulating mass media news contents in workshop setting	multiple media (games, pictures, graphs, flipchart)	perception of CC	not addressed	not addressed
Mycoo, 2015	Music and dance videos, participatory GIS featuring 2D and 3D maps, and digital, online learning materials	music and dance videos, maps, PGIS, digital, online learning	awareness, perception, understanding, knowledge of CC, causes, risks, and impacts, learning	positive responses towards videos	adaptive capacity building
Newell and Dale, 2015	Electronic communication, digital, internet-based channels such as blogs, chats	digital	not addressed	not addressed	participation as attention and interaction with social media contents, liking in social media, sharing
Williams et al., 2015	Social media platform, Twitter	digital	not addressed	user attitude towards CC (e.g., sceptic and activist), positive and negative sentiments expressed in text towards target users	engaging in different online interactions and communication with users or communities that hold the same or different attitudes towards CC, acting as "opinion leaders" in online social networks
Chowdhury et al., 2016	Participatory educational theatre (PET) to communicate climate change 'problems-solutions'	verbal communication (musical story), no technology involved	awareness, knowledge	interest and attachment to program, motivation to be part of a conservation or a development scheme, popularity of PET in the community	convey information about CC, engagement through PET participation

Article	Communication approach	Media technology	Cognitive engagement	Emotional engagement	Behavioural engagement
Jacobson et al., 2016	Multiple media (materials, paper) used in art making of abstract collages representing climate change processes	multiple media (materials, paper)	awareness, perception, knowledge of causes and impacts of CC, concept building, creative thinking, peer learning	curiosity, emotional connection	create artistic collages for communicating CC, engagement in the production of art
Ndhlovu and Mpofu, 2016	Mass media (print newspapers, broadcast – radio, television), online media, mobile phones	multiple media (print, broadcast radio & television, online media, mobile phones	understanding, meaning making, knowledge of CC impacts and of CC adaptation techniques	trust (in media, in adaptation techniques, in suitability of technique to own context)	adaptation action taking and rejection
Inamara and Thomas, 2017	Paper-based photography and oral storytelling (photo essays)	paper-based photography, oral storytelling	understanding of CC impacts and adaptation, meaning/sense making of CC impacts, social construction of meaning, reflections of shared experience, identify local responses, awareness, learning, knowledge, perceptions (see, feel, hear or think)	attitude change regarding the sustainable traditional practices	transfer of knowledge and skills for CC adaptation, support for action and dissemination of adaptation strategies, dissemination work, community dialogue and discussion, building capacity for adaptation and resilience
Burke et al., 2018	Visual arts based on knitting and audio recording exhibited in the natural environment	physical, knitted artefacts in the nature and audio recording	social, local, and subjective constructions of meanings of CC, awareness, perception, knowledge, learning, reflection (thinking, thought provoking), dismissal of new information or of emotional elements of CC communication, awareness of the interdependence between people and environment, understanding of CC impacts	feelings towards CC (concern, worry, interest), trust and belief in the scientific agreement about the causes of CC, trust is sources, feelings of power/ powerless / confusion in tackling CC; scepticism, place attachment, pro-environmental values, enjoyment/uninterestingness (of engaging with the artwork), attitude change towards CC	pro-environmental behaviour, sense of empowerment of taking steps to tackle CC, dialogical responses, discussion about CC impacts, talking with peers about the issues learned

Arts as communication approach was examined in 6 studies. Two main forms of art were addressed, namely *visual arts* (Burke et al., 2018; Inamara & Thomas, 2017; Jacobson et al., 2016; Harris, 2014; Mycoo, 2015), and *performing arts* (Mycoo, 2015; Chowdhury et al., 2016). Combining different forms of presentation was common among the studies; for example, dance and music were presented in a video recording format (Mycoo, 2015), and visual arts were accompanied with oral presentations or audio recording (Burke et al., 2018; Harris, 2014; Inamara & Thomas, 2017). Visual arts were employed in 5 studies and included photography and photo essays, knitted birds, abstract collages of paper and natural materials such as stone and plants, videos of dance, music, indigenous knowledge, and customs. Moreover, oral communication of traditions using storytelling or music was very important in indigenous, traditional, or rural communities (Chowdhury et al., 2016; Harris, 2014; Inamara & Thomas, 2017; Mycoo, 2015). On the other hand, visual arts using traditional rather than modern technology were equally observed in developed and developing countries (USA, Canada, Fiji, and Papua New Guinea).

A concept matrix was constructed (Table 9) to summarize the communication approaches by country, type of public, and type of response. It is observed a relative *lack of studies addressing news media as interactive and participatory forms of communicating climate change issues in developed countries*. On the other hand, in these countries the focus was more on ICT-based approaches using social media, visualizations, simulations, and games. *It is also observed a recent trend of exploring traditional forms of communication such as arts*. In the developing economies, there are examined traditional print or modern news channels, as well as ICT methods and art-based, traditional or oral communication. ICT-based methods for communicating climate change in developing and vulnerable communities are especially used for adaptation responses as part of capacity building efforts.

Most works addressed multiple *media technologies* including digital technologies (10), while some focused solely on digital or computer-based media (6). It is interesting to notice also that the traditional paper as medium was used only marginally in 6 studies without being the focus of systematic research. Thus, paper as medium only appeared in the following forms: digitally archived newspapers (Salathong, 2013), paper photography or paper as materials for artistic collages (Jacobson et al., 2016; Inamara & Thomas, 2017), newspapers or printed reading materials (Ndhlovu & Mpofu, 2016; Khan et al., 2012) and paper maps (Lieske et al., 2014).

Table 9. Overview of communication approaches in empirical studies

Communication approach	Countries	Years/paper	Type of public	Response
News media 4	developing: 4	Khan et al., 2012	p + f + l + t	a
		Salathong, 2013	s	m
		Fernandez et al., 2015	i	a
		Ndhlovu and Mpofu, 2016	f	a
ICT based 9	developed: 5	Pereira et al., 1999	h	m
		Wibeck et al., 2013	p + s	m
		Lieske et al., 2014	h + p + l	a
		Schroth et al., 2014	p + s	m + a
		Newell and Dale, 2015	p + h	m + a
	n/a: 1	Williams et al., 2015	h	n/a
	developing: 3	Fernandez et al., 2015	i	a
		Mycoo, 2015	l + s	a
		Ndhlovu and Mpofu, 2016	f	a
Arts 6	developed: 2	Jacobson et al., 2016	s + t	m + a
		Burke et al., 2018	t + l	m + a
	developing: 4	Harris, 2014	l + p + i	m + a
		Mycoo, 2015	l + s	a
		Chowdhury et al., 2016	l	a
		Inamara and Thomas, 2017	l + i	a

Abbreviations: Type of public: p = professionals or experts; s = students; f = local farmers; l = local communities; t = tourists (visitors); h = heterogenous (e.g., Twitter communities); i = indigenous or traditional communities. Response: m = mitigation, a = adaptation.

5.7 Interactive approaches

Four types of interactivity were identified, that could co-exist in the same study or same communication approach:

1) human-computer interaction for navigation and attending dynamic presentations,

2) interaction with media contents for meaning making,

3) interaction with media technology for creating content, and

4) social interaction.

The first category, **human-computer interaction**, included interaction with game controls (Schroth et al., 2014), visualization systems (Lieske et al., 2014; Pereira et al., 1999), and social media (Newell & Dale, 2015; Williams, 2015). The second category, **interaction with media contents for meaning making**, included interaction with computer-based models or visualizations that presented issues regarding climate change such as prediction of impacts (Lieske et al., 2014; Pereira et al., 1999), game play (Schroth et al., 2014), interaction with artworks (Burke et al., 2018), interaction with news content for meaning making (Ndhlovu & Mpofu, 2016). Third, **interaction with media technology for creating content** was mainly studied in three case studies of art making (Harris, 2014; Inamara & Thomas, 2017; Jacobson et al., 2016). Finally, **social interactions** were identified between peers in working groups (Chowdhury et al., 2016; Harris, 2014; Pereira et al., 1999; Salathong, 2013), between audience and

presenters/facilitators (e.g., Chowdhury et al., 2016; Fernandez et al., 2015; Inamara & Thomas, 2017; Khan et al., 2012; Mycoo, 2015; Pereira et al., 1999; Wibeck et al., 2013), mediated by technology such as online chats or social media (Newell & Dale, 2015; Williams et al., 2015), or simulated by technology such as in virtual worlds resembling reality (see Schroth et al., 2014).

The concept matrix in Table 10 summarizes these interactive approaches by country, type of media, type of public and type of response. Most of the studies included both *human-media interactions* and *social interactions*, however there were a few studies that only included explicitly either social interactions (Chowdhury et al., 2016; Harris, 2014; Khan et al., 2012) or human-media interactions (Burke et al., 2018; Lieske et al., 2014). Not every study stressed the interaction with content for meaning making, except in the ones mentioned above. Table 10 shows *a lack of empirical studies examining content creation in news media, social media, as well as other ICT-based communication forms such as games, visualization or simulation models*.

Table 10. Overview of interactive approaches in empirical studies

Interactive approach	Countries	Years/paper	Type of media	Type of public	Response
Human-computer interaction	developed: 4	Pereira et al., 1999	simulation, visualization	h	m
		Lieske et al., 2014	visualization	h + p + l	a
		Schroth et al., 2014	game	p + s	m + a
		Newell & Dale, 2015	social media	p + h	m + a
	n/a: 1	Williams, 2015	social media	h	n/a
Interaction with media contents for meaning making	developed: 4	Pereira et al., 1999	simulation, visualization	h	m
		Lieske et al., 2014	visualization	h + p + l	a
		Schroth et al., 2014	game	p + s	m + a
		Burke et al., 2018	artwork	t + l	m + a
	developing: 1	Ndhlovu and Mpofu, 2016	news media, ICT	f	a
Interaction with media technology for creating content	developed: 1	Jacobson et al., 2016	artwork	s + t	m + a
	developing: 2	Harris, 2014	artwork, video making	l + p + i	m + a
		Inamara and Thomas, 2017	artwork	l + i	a
SI between peers	developed: 1	Pereira et al., 1999	simulation, visualization	h	m
	developing: 3	Salathong, 2013	news media	s	m
		Harris, 2014	artwork	l + p + i	m + a
		Chowdhury et al., 2016	artwork	l	a
SI between audience and presenters	developed: 2	Pereira et al., 1999	simulation, visualization	h	m
		Wibeck et al., 2013	visualization	p + s	m
	developing: 4	Khan et al., 2012	news media	p + f + l + t	a
		Fernandez et al., 2015	news media, ICT	i	a
		Mycoo, 2015	artwork, ICT	l + s	a
		Inamara and Thomas, 2017	artwork	l + i	a
SI mediated by technology	developed: 1	Newell & Dale, 2015	social media	p + h	m + a
	n/a: 1	Williams, 2015	social media	h	n/a
SI simulated by technology	developed: 1	Schroth et al., 2014	game	p + s	m + a

Abbreviations: * SI = social interaction; Type of public: p = professionals or experts; s = students; f = local farmers; l = local communities; t = tourists (visitors); h = heterogenous (e.g., Twitter communities); i = indigenous or traditional communities. Response: m = mitigation, a = adaptation.

5.8 Participatory approaches

In the reviewed articles, participation was found to be associated with various actions that involve the study participants. Participatory communication approaches and participatory media were mostly observed in the primary studies as means to:

- **co-create** together with other community members presentations about climate change (see Harris, 2014; Inamara & Thomas, 2017; Jacobson et al., 2016), and
- **communicate** with peers or presenters/facilitators (see Chowdhury et al., 2016; Fernandez et al., 2015; Harris, 2014; Inamara & Thomas, 2017; Khan et al., 2012; Mycoo, 2015; Newell & Dale, 2015; Pereira et al., 1999; Williams et al., 2015).

Furthermore, public participation had also the following forms:

- **participation in events and research projects** such as in one-way dissemination of climate change information or engagement interventions (Burke et al., 2018; Lieske et al, 2014; Newell & Dale, 2015),
- **participation in workshops to increase empowerment and engagement** through learning about sustainable alternative activities and through increasing awareness (Pereira et al., 1999; Salathong, 2013; Schroth et al., 2014),
- **participation in climate change adaptation actions** as enabled by communication media such as radio, phone calls and communication with opinion leaders (Ndhlovu & Mpofu, 2016).

Participation and participatory approaches were also equated with taking into account the users characteristics in the communication process:

- **participation of public in the communication process by mapping audience segments** to their level of knowledge and understanding (Wibeck et al., 2013),
- **participation of public in the communication process by identifying stakeholders and targeting** the communication accordingly (Khan et al., 2012).

The concept matrix in Table 11 maps the studies according to their participatory approach. Some studies covered multiple perspectives on participation, such as included a co-creation exercise along communication with peers or presenters/facilitators (see column 4, Secondary type). Empowerment as participatory approach is especially visible in studies with public from developed countries, while co-creation is employed in developing countries, where empowerment is seen as a desired outcome.

Table 11. Overview of participatory approaches in empirical studies

Participatory approach	Countries	Years/paper	Secondary type	Type of public	Response
Co-creation	developed: 1	Jacobson et al., 2016		s + t	m + a
	developing: 2	Harris, 2014	Communication	l + p + i	m + a
		Inamara and Thomas, 2017	Communication	l + i	a
Communication	developed: 2	Pereira et al., 1999	Empowerment	h	m
		Newell & Dale, 2015	Awareness	p + h	m + a
	n/a: 1	Williams, 2015		h	n/a
	developing: 6	Khan et al., 2012	Target audience	p + f + l + t	a
		Harris, 2014	Co-creation	l + p + i	m + a
		Fernandez et al., 2015		i	a
		Mycoo, 2015		l + s	a
		Chowdhury et al., 2016		l	a
		Inamara and Thomas, 2017	Co-creation	l + i	a
Awareness/ Engagement event	developed: 3	Lieske et al., 2014		h + p + l	a
		Newell & Dale, 2015	Communication	p + h	m + a
		Burke et al., 2018		t + l	m + a
Empowerment/ Engagement workshop	developed: 2	Pereira et al., 1999	Communication	h	m
		Schroth et al., 2014		p + s	m + a
	developing: 1	Salathong, 2013		s	m
Adaptation action	developing: 1	Ndhlovu and Mpofu, 2016		f	a
Segment/ Target audience	developed: 1	Wibeck et al., 2013		p + s	m
	developing: 1	Khan et al., 2012	Communication	p + f + l + t	a

Abbreviations: Type of public: p = professionals or experts; s = students; f = local farmers; l = local communities; t = tourists (visitors); h = heterogenous (e.g., Twitter communities); i = indigenous or traditional communities. Response: m = mitigation, a = adaptation.

5.9 Engagement dimensions

To answer the second research question (*How is engagement with climate change operationalized in the selected studies?*), the outcome of media consumption was examined. All three types of engagement were identified: cognitive, emotional, and behavioural.

Table 8 presents the results individually for each study. Twelve studies out of 16 addressed to some extent all three dimensions of engagement: cognitive, emotional, and behavioural. *Emotional engagement was the least covered dimension in the reviewed studies*; three of them did not address this aspect at all (see Harris, 2014; Fernandez et al., 2015; Newell & Dale, 2015). Fernandez et al. (2015) focused solely on perception of climate change. Newell and Dale (2015) instead addressed only behavioural engagement in terms of participation in social media discussions and information sharing. Harris (2014) examined the effects of participatory video for raising awareness, women empowerment, and capacity building in a local, rural community. Another general finding is that the effectiveness of media and communication approaches was reported using a wide range of individual concepts or constructs, rather than using a systematic and analytical framework.

The **cognitive engagement** dimension had the highest number of responses identified. These ranged from awareness to knowledge, learning, reflection, and meaning making. Meaning making was especially observed in recent studies starting from 2016 (Ndhlovu & Mpofu, 2016; Inamara & Thomas, 2017; Burke et al., 2018). Moreover, the awareness, perceptions, understanding, knowledge referred to different issues defining the phenomenon of climate change: climatic patterns, causes, risks, impacts, responsibilities, and solutions.

Emotional engagement was less reflected in the reviewed studies. The variety of individual emotions was less systematically studied compared to the case of cognitive dimension. Examples of emotional responses to mediated communication of climate change include suspicion, scepticism, rejection, threat, appeal, alertness, empathy, scare, interest, relevance, concern, shock, the feeling of urgency, attitudes, positive responses, positive and negative sentiments, motivation to act, attachment to program, media popularity, curiosity, emotional connection, trust, belief, attitude change, worry, pro-environmental values, place attachment, enjoyment, disinterest. These emotions are observed as responses to media, climate change, informational contents, sources, scientific agreement, place, environment.

Finally, **behavioural engagement** was addressed in all studies, highlighting various ways that public can be engaged to act in response to climate change challenges. The following types of actions have been identified: 1) ***pro-environmental behaviour*** or intentions to adopt sustainable behavior to mitigate climate change (Pereira et al., 1999; Salathong, 2013; Schroth et al., 2014; Burke et al., 2018); 2) ***intentions to take responsibility to mitigate*** climate change (Pereira et al., 1999; Schroth et al., 2014); 3) ***capacity and resilience building***, i.e., building and practicing skills to adapt to climate change (Khan et al., 2012; Harris, 2014; Mycoo, 2015; Inamara & Harris, 2017); 4) ***decision making*** (Khan et al., 2012; Wibeck et al., 2013); 5) ***empowerment, agency, and community participation*** (Harris, 2014; Burke et al., 2018); 6) actions or intentions to ***increase awareness, knowledge transfer, and information dissemination*** (Harris, 2014; Lieske et al., 2014; Newell & Dale, 2015; Williams et al., 2015; Chowdhury et al., 2016; Jacobson et al., 2016; Inamara & Harris, 2017; Burke et al., 2018); 7) ***intention for political and social involvement*** to adapt to climate change (Lieske et al., 2014); 8) ***adaptation intentions of moving*** to other places (Lieske et al., 2014); 9) ***taking or rejecting adaptation*** actions (Ndhlovu & Mpofu, 2016); and 10) ***support for adaptation action*** (Inamara & Harris, 2017).

5.10 Evidence of effectiveness and challenges

To answer the third research question (*What works well and what challenges exist relative to the effectiveness of interactive and participatory approaches in triggering engagement with climate change?*), the results of the empirical studies in relation to media characteristics were examined. The studies were diverse in terms of approaches and observed effects of the participatory and interactive communication, making difficult to identify general patterns of effectiveness towards climate change adaptation and mitigation. However, generally, most of the studies showed a **positive effect** in terms of

increased awareness, understanding, and knowledge about climate change issues. Thus, the following two general findings are enounced:

- *E1: Interactive and participatory mediated communication in its various forms triggers cognitive engagement and thus contributes to agenda setting.*
- *E2: Emotional and behavioural engagement were more difficult to attain or demonstrate.*

Furthermore, several **positive effects of interactive and participatory media** were found, that are listed below as propositions (P1-P11) and are accompanied with example references:

- P1: Interactivity features work well when communicating uncertainties and they facilitate engagement and understanding (Pereira et al., 1999).
- P2: Social interaction and interaction with different media increase attention, interest, and engagement (Newell & Dale, 2017; Wibeck et al., 2013).
- P3: Interactions with media content and context trigger empowerment, engagement, and meaning making regardless of the medium (Burke et al., 2018; Ndhlovu & Mpofu, 2016; Salathong, 2013).
- P4: Dynamic and interactive visualizations of relevant contents are effective in rising awareness and a sense of responsibility to act (Lieske et al., 2014; Pereira et al., 1999; Schroth et al., 2014).
- P5: Personal-, local-, and community-relevant communication features are linked with increased awareness, engagement, involvement, and willingness to act (Khan et al., 2012; Lieske et al., 2014; Pereira et al., 1999; Harris, 2014; Wibeck et al., 2013).
- P6: Simulation models using visualization or game paradigms (Pereira et al., 1999; Schroth et al., 2014) are successful in raising awareness and understanding of individual and collective responsibilities to mitigate climate change.
- P7: Participatory approaches involving public in awareness programs and decision making are implemented both in vulnerable communities (Khan et al., 2012; Harris et al., 2014; Fernandez et al., 2015; Mycoo, 2015; Chowdhury et al., 2016; Inamara & Thomas, 2017) and in developed countries (Burke et al., 2018; Newell & Dale, 2017) by using specific means such as artistic works, online communication, ICT.
- P8: Participatory approaches work well when communication is targeted to relevant stakeholders and audiences and to this end, stakeholder analysis approaches are useful (Khan et al., 2012; Fernandez et al., 2015; Mycoo, 2015; Chowdhury et al., 2016).
- P9: Audience segmentation prior to the presentation (to tailor the presentation to audience characteristics in terms of knowledge, understanding, concern, preferences, values and beliefs) overcomes some difficulties that can hinder the communication process (Wibeck et al., 2013).
- P10: Participatory artworks, including performing arts such as theatre and music, as well as participatory photo-elicitation are effective communication forms, capable to

increase engagement in both developed and developing societies (Burke et al., 2018; Chowdhury et al., 2016; Harris, 2014; Inamara & Thomas, 2017; Jacobson et al., 2016; Mycoo, 2015).

- P11: Indigenous and rural populations rely mostly on oral traditions, thus folk media including dance, music, theatre are the most effective communication means in these communities (Inamara & Thomas, 2017; Harris, 2014; Mycoo, 2015; Chowdhury et al., 2016).

The following **practical challenges** (denoted below by C1-C8) regarding the communication of climate change have been identified, some of which are specific to interactivity and participation, and others are more general and related to content and language:

- C1: Participatory approaches in vulnerable communities require that communication is targeted to relevant stakeholders and audiences. To make this possible, familiar and accessible media as well as locally relevant and personally relevant framing should be employed (Fernandez et al., 2015; Mycoo, 2015; Chowdhury et al., 2016). Fernandez et al. (2015) showed that presentations accompanied with two-way communication via workshops and various mediated information on climate change are not *per se* successful for indigenous people. A possible explanation is that for indigenous people beliefs, personal values, and cultural factors have a decisive influence on shaping the perceptions of and engagement with climate change. In a real world setting of media consumption, communities in rural areas in Zimbabwe expected the information in media to be relevant to their lifestyle (on the other hand, media focus on unaffordable and irrelevant techniques for the local communities induced issues of trust and local farmers built their own ways of adaptation, see Ndhlovu & Mpofu, 2016). In indigenous and rural communities, the poverty and the limited literacy as well as the lack of modern communication technologies made some media inaccessible. This context demands using oral communication and/or a mix of communication modes that are suitable and targeted to each community (Mycoo, 2015).

- C2: The media content and the challenges stemming from the structural problems governing the media content's distribution can interfere with the communal farmers' interaction with media content and the process of meaning making. Thus, if individuals perceive media communicate unreliable information, the same individuals decrease their trust in media. To cope with this situation, farmers would retort to mixing the media predictions with own farming experiences, local knowledge, and opinion or community leaders (Ndhlovu & Mpofu, 2016).

- C3: The language of communication used in news media must match the public characteristics; journalists and science should cooperate to translate climate jargons into easy to interpret terms for the farmers or the public in general. Native languages are more effective due to low literacy levels in some regions, while the use of jargons makes the communication ineffective (Ndhlovu & Mpofu, 2016).

- C4: In written news media, though from the readers' perspective it is ideal to have all four the so-called HOPE aspects in an article (*Holistic approach* addressing both local

and global issues regarding society, environment, and economy; *future-Orientation* through addressing the needs of future generations; *Participatory approach* through framing the news to foster active participation, engagement, and agency of change; *Empowering approach* through providing knowledge about environment, promotion of relevant values, and skills to make a change; Salathong, 2013), this is not always possible and realistic from the journalistic and editorial perspectives (Salathong, 2013).

- C5: In social media, individuals tend to interact and communicate in echo chambers where people of similar opinions gather. These single-view (e.g., sceptics or activists) networks hinder the exchange of information with people of different views (Williams et al., 2015).
- C6: For game design there is the challenge to provide experiences that effectively foster engagement with climate change. The study by Schroth et al. (2014) showed that no strong effects were observed in changing people's concern and attitudes, except those regarding the locality of the phenomenon and the local responsibility to respond to climate change.
- C7: In digital media, especially in visual presentations, audience or users should be enabled to control the visualization parameters based on own interests (Wibeck et al., 2013; Pereira et al., 1999).
- C8: Accuracy of visual, simulation or computational models is very important because it improves models' credibility and it triggers users' trust in the models (Pereira et al., 1999).
- C9: The essential attributes of a model for users and the public are the ease of use and ease of interpretation of the visual format (text, tables, maps, etc.), the explanatory power of the model, relevance to their own experiences / regions / time, "what can I do"? type of information, and fun, interactivity and quality of the visualization, including animation features (Lieske et al., 2014; Pereira et al., 2013).
- C10: Long-term effectiveness of participatory media such as participatory video making and storytelling calls for the availability and effort in maintaining a communication network and consistent mentoring support (see Harris, 2014 for a case of indigenous communities).

5.11 Consolidating the empirical findings with the findings from literature reviews

Four literature reviews (Flood et al. 2018; O'Neill & Smith, 2014; Schäfer, 2012; Carvalho et al., 2017) were found relevant for this review because they addressed to some extent participatory and interactive media for communicating climate change and their effect on engagement (Table 11).

Table 12. Selected literature reviews and non-empirical studies

Title and year	Type of media	CC response	Engagement	Review method
Flood et al., 2018	Games (serious games)	Adaptation	Social learning	Systematic review
O'Neill and Smith, 2014	Visualization	Adaptation and mitigation	Cognitive, emotional, behavioural, political engagement	Narrative review
Schäfer, 2012	Online and social media (Internet, blogs, etc.)	Adaptation and mitigation, but not explicitly stated	Cognitive and behavioural (communication, awareness raising, increasing knowledge, changing behaviour)	Narrative review
Carvalho et al., 2017	Media alternatives	Adaptation and mitigation	Political engagement	Narrative review

Flood et al. 2018 reviewed the literature on serious games employed for educating stakeholders about adaptation to climate change. The engagement was operationalized as *social learning* which can trigger all forms of engagement (cognitive, emotional, and behavioural) via three categories of learning, namely cognitive, normative, and relational (Baird et al., 2014). The second literature review (O'Neill and Smith, 2014) examined research on visual representations of climate change and public engagement with visual imagery across a multidisciplinary array of communication corpora including the news media, NGO communications, advertising, marketing, climate science, art, and virtual reality systems. Engagement was viewed within all three paradigms: *cognitive, emotional, and behavioural,* including *political engagement*. The other two reviews addressed mainly online and social media (Schäfer, 2012) and alternative media (Carvalho et al., 2017). While the review and research agenda by Carvalho et al. (2017) focused mainly on *political engagement*, Schäfer's review discussed all types of engagement (*affective, cognitive, and conative or behavioural*).

The literature reviews strengthen some of the empirical findings enounced previously. Generally, serious games were found successful at triggering *cognitive learning* by increasing knowledge and understanding of climate change adaptation solutions and outcomes. It was found generally more difficult to measure *normative learning* that aims at changes in beliefs and values. However, in some cases these changes occurred by means of *reflection* that determines the participants to change their views of the environment and the decision-making (see Driscoll and Lehman, 2015 as cited by Flood et al., 2018). These findings are in line with the proposition E1 and to some extent with E2, while stressing the *positive role of reflective learning* in increasing emotional engagement. Furthermore, it was found that games also accomplished a *relational learning* function which enabled the players to learn to interact with various stakeholders and understand their perspectives. Thus, through the social interaction afforded by games via various game design mechanisms such as *role-play, story, and language*, the games triggered relational learning (e.g., Ahmer 2013; Eisenack, 2013), which is a form of behavioural engagement. Thus, propositions P2, P3, P6, P7, P9 are strengthened and supported by the context of game design and game play that allow for social interaction and participation. At the same time these findings provide resolutions to the challenges C1, C2, C3 and C6 regarding framing and relevance of media to context and participants.

Flood et al.'s review showed also that *well-performed facilitations and communication* are crucial for ensuring that the participants engage with the game and that the aim of the game is fulfilled, namely it triggers positive experience, co-learning, empowerment, responsibility, participation, and engagement. This finding consolidates the proposition P2 about the role of social interaction in triggering engagement, stressing that social interaction should be meaningful and directed towards fulfilling specific functions such as (co-) learning and empowerment. Furthermore, it was shown that skilled facilitation is achieved through (1) meaningful and engaging narrative and framing (Salvini et al., 2016) and (2) good skills at knowing how to lead the audience (Parker et al., 2016). These findings provide support and solutions for challenges C1 and C3 by pointing out design examples that work in games. *Interaction* among players was also found to facilitate engagement with the game and to impact the effects of decision making in a game where scientists and various stakeholders were engaged in reflexive learning (see Driscoll and Lehman, 2015 cited by Flood et al., 2018). This finding consolidates the proposition P2. Thus, *collaboration* and *dialogue* between players and/or with stakeholders have been found to facilitate the co-production of knowledge, co-produced understanding, and social learning (Flood et al., 2018 citing Driscoll and Lehman, 2016 and Parker et al., 2016). This finding consolidates P2 and P3 and responds to C2. Flood et al. identified also that game features such as *visualization* (Ahmer, 2013; Villamor & Badmos, 2015), *participatory game design* (d'Aquino & Bah, 2013) and *participatory workshops* (Joffre et al., 2015) were successful in triggering positive outcomes such as ownership of the model, engagement with the game, and social learning; these again support previous findings (P1-P4, P6-P10) and provide answers to various challenges including (C1, C2, C6, C7) in the context of game design or other type of media production.

Regarding participatory approaches to visualization, two types of communication approaches were identified in the review by O'Neill and Smith (2014): *3D landscape visualizations* that engage the public sphere in meaning making and decision making, and *the photo-elicitation or photo-voice* that engage the private sphere in meaning making and empowering actions. Both types of visualizations are characterized by being realistic and co-constitutive, attributes that facilitate awareness, understanding, self-efficacy, and behavioural engagement at individual and group/public level (e.g., Sheppard, 2005; Cohen et al., 2012; Baldwin & Chandler, 2010). According to O'Neill' and Smith's review, the interactive and participatory 3D landscape visualizations aim at *empowerment* through visualizing potential climate futures, facilitating dialogue, deliberation, and decision-making regarding climate change response management (Burch et al., 2010), while the photo-elicitation aims at increased *connection* of the individuals with the topic of climate change and at fostering researchers' understanding of the individual values and norms that are important to the them (Baldwin & Chandler, 2010). Thus, visualization through different affordances such as scenario visualization, dialogic interaction, deliberation, and decision-making empowers the public by providing means to learn, interact with peers or decision makers, reflect and make decisions regarding the environment and climate change. This supports the propositions P1-P4, while calling for further explorations regarding the public deliberation and decision-making through visualization-based interactive and participatory media.

In the present review of empirical studies, the two visualization studies employed 3D landscape visualizations that were implemented at different scales; one geospatial view

(Wibeck et al., 2013) and the other included a downtown animation and a GIS map (Lieske et al., 2014). Furthermore, the game study by Schroth et al. (2014) implements exactly the type of 3D landscape visualization about which O'Neill and Smith discuss in their review. However, the findings of these empirical studies are mixed in terms of strength of evidence and positive effects. Lieske et al.'s (2014) study, which compares different visual communication approaches, showed positive effects of visualization media on raising risk awareness and political engagement in terms of quantitative and qualitative findings, respectively. Furthermore, Lieske et al. indicated that participants in the study exhibited an emotional connection to the local environment after being exposed to locally framed animated visualizations, thus the 3D landscape visualizations are also means to influence the private sphere in that they provide support for individual connectedness with the climate change topic in a similar way as photo-elicitation and co-creation do (propositions P5 and P10). On the other hand, Wibeck et al.'s visualization elicited more mixed results in that some participants recognized the usefulness of the visual communication for raising interest, education, decision making and science communication, and some criticized the approach of not being useful for getting new knowledge or not being relevant to the aim or own expectations. Furthermore, the visual realistic game described by Schroth et al. failed to provide strong positive evidence about its effectiveness in raising concern and responsibility to act. The authors pointed towards the small and inappropriate sample of participants as these were students and not locally connected with the visualization. This finding supports the propositions that communication approaches and systems need to weigh the characteristics of the audience, users, and participants (propositions P5 and P9).

According to O'Neill and Smith (2014), *arts and artists* represent notable vectors of shaping climate change engagement through creative representations and imagination (Buckland, 2012; Cameron et al., 2013; Giannachi, 2012; Yusoff & Gabrys, 2011 cited in O'Neill & Smith, 2014) and require further research and explorations as to identifying the actual mechanisms of influencing climate change engagement. In the cited articles by O'Neill and Smith, art is shown to be not only a means to communicate and interact with the public to increase awareness and knowledge, but to provoke *alternative views and political perspectives* towards climate change. The present review identified six art-based communication approaches that fulfilled communication functions to increase awareness and knowledge (Chowdhury et al., 2016; Jacobson et al., 2016), but also socio-political functions such as *empowering vulnerable communities* (Burke et al., 2018; Harris, 2014), *community dialogue* (Burke et al., 2018; Inamara and Thomas, 2017), and *adaptive capacity building* (Harris, 2014; Inamara & Thomas, 2017; Mycoo, 2015). Again, the present review findings showed that art-based communication including photo-making and photo-elicitation does not only affect the private sphere as indicated by O'Neill and Smith (2014), but also has the potential to influence the public sphere by providing means to empower communities with skills and knowledge relevant to their environment (propositions P10 and P11).

In contrast to the positive perspective that visualization, games, and arts offer to climate change communication and engagement, social media and online communication have been criticized as to the low quality of debates and the limited coverage of scientific information (see Schäfer, 2012). Furthermore, the information presented by some corporations to engage the public was shown being biased and deceptive by triggering

the so-called capitalistic agency (see e.g., Smerecnik & Renegar, 2010; cf. Schäfer, 2012) in that certain corporates look for pro-environmental public support to actually legitimize their industrial practices that maintain the environmental crisis. Moreover, Schäfer pointed out that the social interaction observed in online communication is not very meaningful, it occurs in fragmented (the so-called echo-chambers, O'Neill & Boykoff, 2012) rather than in inter-connected communities, and, when perspectives differ, the communication is rather aggressive instead of constructive (Gavin, 2010; Malone & Klein 2007). Similarly, Carvalho et al. (2017) pointed out that alternative discourses in the public sphere form in enclaves that get limited visibility in the mainstream media and discourses, despite that the civil societies which initiate these discourses look for collaboration with the policy makers.

Given this context of social and online communication, Carvalho et al. (2017) highlighted the importance of political engagement as a form of active involvement of citizens in climate change discourse and policy making. Communication of climate change issues thus should be seen as a constitutive practice, and not simply a transmission of information. Furthermore, Carvalho et al. indicated the necessity to construct *alternative discursive spaces and communication practices* where political engagement can be actually performed and not only influenced. In their new review, it was also stressed that bottom-up and rather than top-down participatory approaches should be explored and facilitated for example through action-research projects (Carvalho et al., 2017). In this respect, internet and new media built on advanced information and mobile technologies should have a crucial role in fostering grass-roots climate change initiatives (Carvalho, 2010).

The empirical studies analysed in the present review with respect to participatory and interactive forms of communication indicated that indeed currently social media is a space where individuals gather to reconfirm their own views rather than to exchange and co-constitute new meanings (Williams et al., 2015). Research on online media showed also that people listen to opinion leaders or influencers (Ndhlovu & Mpofu, 2016; Williams et al., 2015). On the other hand, initiatives to communicate scientific findings and projects in social media platforms did not raise a great public interest; instead providing constantly updated project blogs and online dialogues were received with more interest and popularity (Newell & Dale, 2017). Popularity was also associated with the expert facilitation and moderation of these online communication approaches (Newell & Dale, 2017). However, it was found that bottom-up initiatives where public engages in two-way live chats with official representatives were not prevalent, but when taking place these communication practices were very positively appraised by all (Newell & Dale, 2017). Thus, the literature reviews and the empirical findings related to online and social media support the proposition of facilitated social interaction (P2), the challenge of echo chambers in social media (C5) and *provide support for creating interactive and participatory online spaces for meaningful communication*.

Overall, the empirical and literature review findings indicate positive engagement outcomes in the use of visualization- and arts-based communication media. The findings indicate also opportunities for advancing further these approaches as well as the social, online, and game media approaches, especially by harnessing their ICT capabilities.

6 Discussion

This paper introduced the topic of climate change and climate change communication from the perspective of communication approaches and interactive and participatory media. It presented a detailed snapshot of empirical research carried out by the end of 2018. The aim was to provide an overview of research and to identify areas of future research to contribute to the climate change engagement through interactive and participatory media. The literature review showed that while generally the research on climate change communication is widespread, the area of interactive and participatory media is not systematically explored and that empirical studies are deficient, though the existing studies indicate positive effects on engagement. Thus, this review identified research gaps that need to be addressed in future research.

The search protocol yielded 16 empirical studies and 4 relevant literature reviews. The empirical studies were characterized based on research methods, context of study such as country and year, communication approaches, interactive and participatory approaches, and engagement dimensions. The literature reviews were mainly analysed on engagement dimensions and interactive/participatory approaches. The detailed synthesis of the findings represents the answers to *the research questions* and describes 1) the extent to which research on climate change communication touches upon interactive and participatory communication approaches of climate change issues, 2) the way engagement is operationalized; and 3) what works well and what practical challenges exist in the area.

A positive finding was that the share of studies covering developing countries was 50 per cent, showing that research communities in different fields (e.g., social sciences, environmental sciences, communication) recognize the need of investigating and implementing measures where the risks and magnitude of climate change impacts are estimated to be among the highest according to the IPCC (IPCC 2018). In these countries, most of the studies focused on adaptation (6 studies out of 8). In developed economies the focus was mainly on both adaptation and mitigation (4 studies out of 8). The detailed analysis of the reviewed corpus showed that the empirical studies *in the developing countries had the following characteristics*:

- They employed mainly qualitative research approaches.
- They focused on various categories of public including locals, farmers, and indigenous populations, but also tourists, students, and different categories of professionals.
- They predominantly analysed news media and arts, and to a lesser extent ICT-based media.
- They chiefly covered interactivity in terms of social interactions rather than interactions with technology, and in the latter case the focus was on creating or co-creating content.
- They employed participation mainly as co-creation and communication.

- They addressed engagement at cognitive, emotional and behavioural levels and a recurrent aim was the public to develop 1) a sense of risk, 2) a need to learn to adapt to the potential new realities, and 3) the knowledge and capacity to respond to climate change challenges.
- Emotional engagement was less researched in these communities (compared to developed countries) and often focused on trust and motivation to act.

In contrast, the studies *in the developed countries had the following characteristics*:

- They employed mainly mixed methods combining qualitative and quantitative research approaches.
- The public in these studies was also diverse and included locals, students, tourists, and professionals in different domains, heterogenous groups, but did not focus on farmers and indigenous populations.
- They predominantly analysed ICT-based media, and to a lesser extent art.
- They chiefly covered interactivity in terms of human-computer interactions, and interaction with media for meaning making.
- They employed participation in different forms (e.g., co-creation and communication), but also as participating in different actions specifically for empowerment and raising awareness.
- The engagement emphasized more complex notions of cognitive activation (rather than just perceptions of climate change) in that many of these studies focused on triggering a sense of responsibility and developing knowledge on the negative impacts the climate change may bring, thus the behavioural engagement was targeted especially to mitigation actions, sustainable behaviour, including participation in discussions and communication about climate change to others.

Across studies, the media technology and the forms of communication employed were diverse. In developing countries, folk media involving oral communication or performing arts (Onyenankeya & Salawu, 2018; Bhattacharyya & Gupta, 2013) such as street theatre performances, storytelling, music and dance were more positively received by public compared to modern media (Chowdhury et al., 2016; Mycoo, 2015; Inamara & Thomas, 2017). The modern media in the reviewed studies mainly consisted of digital forms of communication.

It was revealed that all three engagement dimensions were addressed, namely, cognitive, emotional, and behavioural engagement; however, these were differently covered across studies. The studies focused especially on cognitive dimensions such as awareness, perceptions, and understanding of climate change issues (climatic patterns, and climate change causes, risks, impacts, responsibilities, and solutions) supporting agenda setting. The issues covered are wide and future research is needed to systematize the results by each type of construct, for example, risks, responsibilities, and solutions. Regarding the type of climate change response, the studies addressed both mitigation and adaptation

problematics, while 5 studies covered both. Adaptation was mainly covered in studies of developing countries, while mitigation was mainly addressed in developed countries, while three studies addressed solely mitigation. Again, the results showed alignment with the IPCC recommendations, namely that, mitigation is crucial in developed countries, where it is essential to decrease the carbon emissions and footprint, while adaptation solutions are especially important in developing countries, where the impacts of climate change may have more catastrophic consequences (e.g., on agriculture, or on indigenous communities whose welfare is highly dependent on the land and nature).

Studying the effectiveness of approaches on engagement in its various forms, it was seen that different ways of interaction as well as participation have positive effects on participants. These effects spanned from raising awareness to decision-making. A series of propositions and practical challenges has been assembled to be researched further and implemented in practical settings. Four relevant literature reviews have been contrasted with these propositions and challenges, and this consolidation provided further support and solutions for future work in the area.

6.1 Research gaps

The reviewed literature yielded also a series of gaps that should be filled. First, regarding research approaches, no meta-analyses were identified in the review, but only one systematic review on games and three narrative reviews on visualization and social/online media which consolidated the empirical findings. However, the area is still largely unexplored empirically, thus meta-analyses may not actually be suitable yet. On the other hand, the area is very active and novel perspectives and literature reviews emerge, for example the review by Pearce et al. (2019) on social media. Further regarding the research approaches, it was observed a lack of intervention studies using quantitative research approaches, especially longitudinal studies and controlled experiments; the strength of evidence in the existing studies is rather low or medium, than high. The quantitative studies lacked appropriate sample sizes, representative participants, or well-established measures.

Second, emotional engagement was less addressed in both the empirical studies and identified literature reviews compared to the extent that cognitive and behavioural engagements were reported. Moreover, the specific constructs of the three dimensions (cognitive, emotional, behavioural) were not systematically shared among different studies, these were of various nature and of different depth of analysis (sometimes, the construct was just mentioned using merely the authors' reflection and without reporting the way it was assessed). Furthermore, political engagement (Carvalho et al., 2017) was covered to a very limited extent in the reviewed empirical articles. Overall, there was a critical lack of systematic and analytic approaches to evaluate the effectiveness of the media and communication approaches when communicating climate change issues. This includes a lack of established constructs and measures for evaluating effectiveness, as well as lack of solid quantitative and longitudinal studies to assess and follow up the impact over time.

Third, the traditional forms of mass media such as print, radio, and television were not studied in-depth in the primary studies, neither in their traditional forms or digitally

enabled (digital mass media). Though social media are covered in the literature, no studies examining or demonstrating instances of innovative, interactive, and participatory forms of traditional but digitalized news media (e.g., digital newspapers or digital television) were found. Thus, despite that theoretical research and empirical studies in adjacent areas such as urban planning shows that participatory media is effective in triggering engagement, no studies of climate change communication using interactive and participatory traditional news media were identified. Furthermore, all the studies illustrating co-creation forms of participation and interaction focused on arts but lacked in the realm of digital media or traditional media.

6.2 Limitations of this study and opportunities for future work

This review tried to be comprehensive and to answer the research questions in an objective manner. However, the obtained findings are by no means without limitations. First, the analysed material covered articles published until end of 2018, when the search was conducted. Second, the review focused only on journal articles as the initial set of articles obtained was very large and it was impossible to screen all articles. Third, though the selection was based on a comprehensive list of keywords, some other search words may have been beneficial to be added such as "community", "engagement". The usefulness of these keywords became apparent only at the time of analysing the data and writing. However, still this review is based on broad search terms (e.g., "communication", "public opinion") and employed the non-exclusive operator "OR" in the search phrases so the coverage of the relevant articles is as broad as possible. Nevertheless, a few articles might have been missed in the systematic evaluation (e.g., Schroth et al., 2015). Another possible limitation of the systematic review is that the analysis was carried out by one researcher only, while more researchers would have ensured perhaps a more objective analysis. The analysis tried however to cover and identify most of the relevant aspects in the primary studies and to structure them into a useful synthesis that can be replicated in a further study. A new search could then be conducted on the basis of the present one, that would include newer articles, chapters and conference papers, as well as refined search terms. Furthermore, different reviews would then be optimal, each narrower in scope and focused on one of the topics identified or on some issues that emerge such as visualization, games and gamification, participatory news media, and corporate social responsibility.

6.3 Research agenda

In the following a research agenda is proposed for advancing the area of climate change communication with the help of interactive and participatory approaches. The research directions are intended to fill the gaps identified with this review. First, there are proposed seven general, strategic, far-reaching directions, and then, three more specific issues.

1. The main gap or limitation revealed with the help of this review was that the empirical studies lacked a common reference framework that would provide the findings more weight in the overall literature on climate change communication. Systematic evaluations of the effects of interactive and participatory media are missing in the reviewed literature, though there are several conceptual tools and theoretical

perspectives available to researchers investigating this area. On one hand, there is a need for systematizing the knowledge available on climate change communication for example by *integrating the existing frameworks and empirical findings* (see e.g., Ballantyne, 2016; Bushell et al., 2016; Moser, 2009; O'Neill & Smith, 2014; Sheppard, 2005), and on the other hand, *the empirical studies should clarify their design in light of theoretical and conceptual frameworks*. I believe that by addressing these two research objectives in future studies, the dialogical and incremental approach to scientific discoveries and research findings in this area should become more transparent and effective in future contributions. Furthermore, *building on frameworks and theories from the psychology and social sciences* (e.g., communication, social psychology, anthropology, cognitive psychology) and *studying them empirically on interactive and participatory climate change communication* would advance the area greatly and provide new and valuable perspectives (e.g., the cultural cognition theory, theory of reasoned action, theory of planned behaviour) on the mechanisms of how cognition, emotions and behavioural intentions lead to long-term behaviour and changes in values and habits.

2. At the start of the review process, it was observed that the literature on climate change news framing and coverage is quite extensive, where the research chiefly focuses on identifying representational patterns in journalism and framing by using content analysis and discourse analysis approaches (see e.g., Brüggemann & Engesser, 2017; Carvalho & Pereira, 2008; Gavin et al., 2011; Olausson, 2009; Schäfer & Schlichting, 2014). However, very few studies examined the effect of framing on public reception and response (see e.g., Olausson, 2011; Sampei & Aoyagi-Usui, 2009). Furthermore, there were not identified any studies on climate change communication in *news media* where interactivity and participation of the public were embedded as media characteristics that would affect the communication process, output and outcomes (see Moser, 2009). The only study coming close to this approach was by Salathong (2013) where framing of the news in terms of participatory and empowering messaging were analyzed, however, here representants of public were evaluating the news framing and contents, and they were not viewed as active producers, but passive consumers of news (see O'Neill & Smith, 2014; Carvalho et al., 2017). Thus, apparently there is a lack in both practice and research in *democratizing the news media* so that the voice/contribution of the public is heard/enabled. There is a need for *action research and interventions to examine possibilities that public can participate directly in the process of news production regarding climate change*; this will alleviate the limitations in the news media imposed by editorial and journalistic policies and resources. Furthermore, *public involvement in the co-design and co-creation actions* regarding climate change visual representations, games, and communication platforms can be integrated in these action research projects and interventions with the help of multidisciplinary researchers from journalism and communication, climate and environmental sciences, urban planning, information systems, computer science, sustainable development, etc.

3. Education and learning about climate change as well as about adaptive and mitigation actions are the primary objectives of climate change communication. However, in many of the reviewed studies including the literature reviews, there are recognized shortcomings in the skillset of the public regarding visual culture (e.g., Lieske et al.,

2014; O'Neill & Smith, 2014) and participatory culture (e.g., Carvalho et al., 2017) while these would be essential for understanding and/or communication. Furthermore, technology advances such as ICT, though promising for enhancing the communication and learning, are not everywhere adopted by the large public (see e.g., Mycoo, 2015) or are less than optimally employed in (mass) communication and participation (see De Cindio & Schuler, 2012; Jenkins, 2006) where the ICT is not used to its full capacity to enable public participation. This state of affairs points towards recognizing that the limits of climate change communication is a problem at the societal/community level rather than individual level and requires a holistic and long-term approach involving research, educational, and professional practice efforts towards enhancing visual and ICT education, promoting participatory approaches in media and communication practice, and building a culture of responsibility and empowerment where community members know what is best for them and their environment and act accordingly. Integrating climate change communication in this holistic vision towards education and participation would translate into a variety of interventions and action research projects including, for example, introducing, establishing, and developing climate change education, media literacy and participatory culture in formal and informal education programs, as well as generating, developing and participating into social platforms similar to Wikipedia and open-source software projects where community contributes with and reflects on alternative views and actions on climate change. Thus, community-driven initiatives to communication and political participation (Carvalho et al., 2017), but also research-, policy- and corporate-driven media initiatives in response to public or consumers demands (see Jenkins, 2006) are needed to engage the public more effectively in climate change actions. Thus, there is a need of creating and researching *interactive and participatory online spaces for meaningful communication*.

4. Climate change is a long-term phenomenon even if the response to it is urgent. Nevertheless, the type of response required is also a long-term engagement, rather than momentary emotions or one-time actions. However, current empirical studies, with very few exceptions, evaluate the media effects from a narrow and short-distance perspective; longitudinal studies focusing on long-term learning and behavioural changes are extremely rare (see for an example, Schroth et al., 2015). In this context, there is a need for systematic controlled experiments where the media components are rigorously isolated and tested over time, but also quantitative (e.g., surveys) and qualitative (e.g., ethnographic) studies that dig deep into the issues of climate change perceptions from psychological and behavioural standpoints. There is a need of various approaches both in the lab and in the field in order to obtain a continuous feedback from the community on how media and communication are doing their part in engaging the public with climate change. Furthermore, research involving communities and different members of the public represents an important channel to capture and transmit the voice of the public regarding the issues of climate change: their attitudes, values, concerns and levels of engagement, and as a consequence the research itself becomes a mechanism for empowering the public and providing them a space for communication.

5. In many studies reviewed as well as in studies outside the scope of the review but belonging to the related and relevant literature, it was difficult to distinguish between

"public" and "individual" level of analysis. Future studies and research in the broader area of climate change communication should address also this issue and clarify when public means community – whose responses are captured and analysed at the group or societal level of analysis, and when public means different persons or members of the general public – whose responses are captured and interpreted/analysed at the individual level. Furthermore, to address this issue, the research studies should clarify the type of sampling, and especially where the public engagement is the target, representative sampling to be the norm in the research design.

6. In empirical studies, there is a need to distinguish between individual and public engagement. Researchers should direct efforts in defining measures for capturing engagement at different levels and stages. Furthermore, there is a need for studying mechanisms that explain and predict how different types of engagement can be triggered and the success of different approaches in achieving the target engagement. Moreover, the links between different types of engagement as well as between engagement at different levels should be studied and elucidated. Last but not least, approaches combining individual and collective/public engagement could be designed in order to elucidate the forming and transforming of individual perceptions into collective knowledge and actions, and the roles media, communication and collaboration have in this respect.

7. Interventions implemented using various research methodologies (controlled experiments, action research) should target both mainstream media and alternative media to involve public in co-creation exercises similar to those in open-source software communities and sharing economy. Effects of these interventions should be studied in systematic ways yielding longitudinal observations and results.

In the following more **specific issues** are suggested. Not all studies showed positive effects of media and communication on engagement, despite that some forms of interactivity and participation were implemented. Though, there is a consensus among recent research that interactivity and participation trigger engagement by providing an experiential learning context that facilitates meaning making (Cooney, 2010; Moser & Dilling, 2011; Wibeck, 2014), the findings in this literature review showed that there are still challenges to achieve the desired outcome in terms of engagement, especially in terms of emotional and behavioural outcomes.

1. From a research perspective, the lack of strong effects should be addressed by ensuring a rigorous research design, including rigorous preparation and implementation of the experimental stimuli incorporating interactive and participatory media elements, as well as carefully taking into account the communication context and social setting, the audience, and the dependent variables as well as selecting and constructing rigorous measures for these variables. Related to games, for example, Maltseva et al. (2019) indicated that games do not necessarily foster engagement with environmental issues. However, in order that games, and in general, interactive systems, to be successful for climate change engagement, they need to be designed for the purpose they are created. For example, if a game is meant to be used for learning (see Flood et al., 2018), then the design should take into account appropriate learning outcomes and activities (Garris et al., 2002), usability and user issues (Rajanen & Rajanen, 2017), as well as

appropriate learning theories (see e.g., Cooper, 1993; Dillon, 2003) to make possible a positive user response.

2. Similarly, participatory approaches should be meaningful, raise interest and foster long-term commitment or far-reaching outcomes to become empowering and deliberative tools for the public. The literature indicates that community and grass-roots initiatives are prone to polarization and fragmentation (Jenkins, 2006; Schäfer, 2012; Williams et al., 2015), while top-down approaches risk to be ineffective because they are often limited to communication to and consultation of the public, but do not empower the participants to have a role in deliberation and decision making (De Cindio & Schuler, 2012; Rowe and Frewer, 2005). To overcome these limits, communication approaches centred around participation in educational contexts and in decision-making contexts should be designed by taking into use various features of online systems, visualization, and games as well as more traditional media and storytelling that enable sustained participation and deliberation. Here, special attention should be given to marginalized communities, including indigenous populations, to whom we need both to listen and learn from and to communicate them the risks and implications of climate change.

3. In cultures or contexts where technology can become a barrier rather than an enabler, arts and folk media should be explored as participatory approaches to foster climate change engagement. Examples in this direction are the photo elicitation approach (Baldwin & Chandler, 2010; O'Neill & Smith, 2014; Wang & Burris, 1997) and participatory video making (Inamara & Thomas, 2017). Similarly, Shaw et al. (2009) pointed out that creative representations beyond the science narrative are important to be explored in visual representations for decision-making to foster novel approaches to climate change communication that depart from the current practices.

6.4 Integrative model

In the following, an integrative model is constructed based on the findings and discussion to bring forth the multiple roles interactive and participatory media have or should have, and how these roles engage the individual at different stages of participation, which in turn will influence both the media landscape, but also the public engagement at macro-level (Figure 8).

In short, the integrative model indicates that the public engagement with climate change has the capability to not only change attitudes and behaviours at large scale, but also to change policies and cultures in the long-term. The changes at the macro-level will feed back to adaptations at the meso- and micro-level. The improved media landscape and the adjustments in individual values, habits, knowledge and skills sets will make possible a new cycle of change and evolution towards even better individual engagement, media landscape, and public participation.

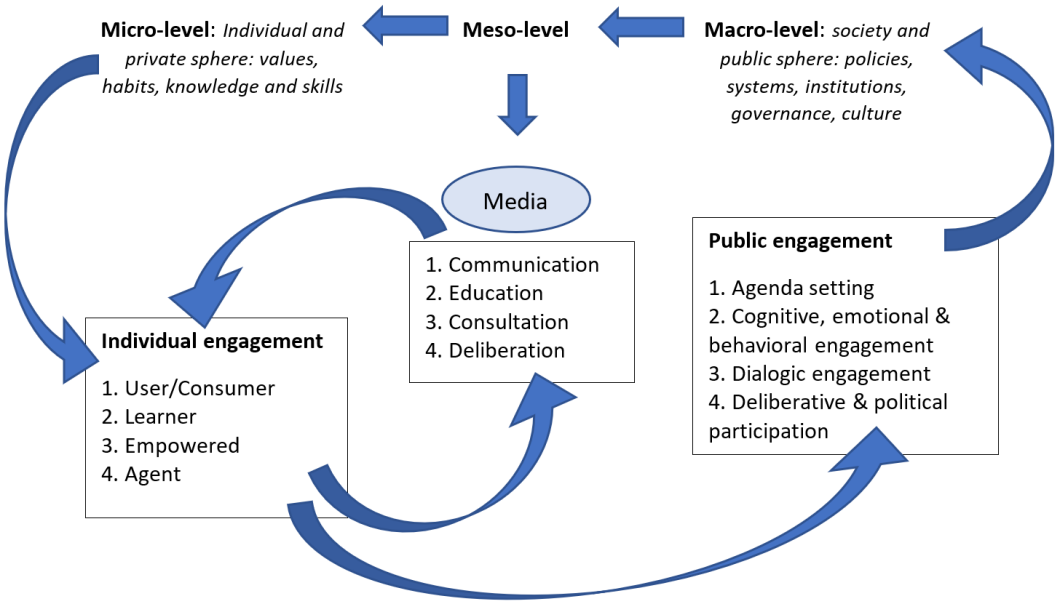

Figure 8. Engagement stages and the roles of media: An integrative model

The public engagement concepts in this framework are adopted from existing conceptualizations (see McCombs & Shaw, 1972; Lorenzoni et al., 2007; Moser, 2011; Moser & Dilling, 2011; Nagda, 2006; Wibeck, 2014). The media roles (communication, consultation and deliberation) are adopted from the three-level model of public engagement described by Rowe and Frewer (2005). Education was added based on the media conceptualization and findings in the literature review (see e.g., Flood et al., 2018; Olson, 1974; Salomon, 1994). The individual engagement concepts (user/consumer, learner, empowered, and agent) are drawn from the literature on climate change communication and empirical findings, as well as from the fields of information systems, participatory design, and civic engagement (e.g., Amichai-Hamburger et al., 2008; Carvalho, 2010; Bødker & Kyng, 2018; Harris, 2014; Raphael et al., 2010; Salathong, 2013).

Currently, media main role is seen as being to communicate climate change issues, and as a result an individual, a member of the public has limited engagement opportunities and thus acts mainly as a user of media platforms and consumer of messages and information about climate change in different formats available. This role ensures that the public engagement occurs at the level of awareness and agenda setting. This is the first stage of engagement, denoted by 1 in the model. Interactivity and participation are implemented to some extent to ensure the communication is successful. The more interactive the communication, the more effective will be this type of engagement and agenda setting. Participation can take different forms such as participation to workshops, events, and audience segmentation.

Research-driven and community-driven interventions aim typically at the higher stages of engagement (stages 2-4). The second stage is achieved by assigning the media an educational role. Participation in events and workshops are typical manifestations of the educational role, and interactive and participatory approaches that involve social and experiential learning such as co-creation are considered the most effective. At this stage,

the individuals are learners. Different types of learning take place: cognitive, normative, relational, civic, reflective (Flood et al., 2018; Gordon & Baldwin-Philippi, 2014). At the society level, this type of individual engagement and learning scale up to notable progress and changes in understanding, knowledge, skillsets, concerns as well as behaviours, such as adaptive capacity building, and small-scale mitigation actions. Thus, the public engagement at this stage is conceptualized by using the established terminology (cognitive, emotional, and behavioural) and can be captured by aggregate indicators for collective response to climate change. The level of attainment at stages 1 and 2 can furnish the macro-level institutional bodies with feedback and policy support, while on the long-term they can lead to changes in culture, orienting the public towards sustainable practices.

In the third stage, media role is to enable participants to voice their interests and perspectives, as well as provide their contributions to the co-creation of media landscape as well as their knowledge and solutions to the climate change issues. Thus, media should represent a platform for consultation and co-creation, and individuals should feel empowered and have equal opportunities to contribute to the climate change discourse and media production. At the society level, this empowerment will translate into a dialogic engagement where public along other stakeholders, such as academia, policy makers, business and media industry will collaborate at least at the level of climate change discourse and media production.

Finally, in the fourth stage, the role of media is to provide a space for deliberation and participation into the decision making related to climate change issues, actions, and policies. The individual citizens become the agents of their own interests and values, having the possibility and capacity, built on the previous stages, to act upon the things that concern and affect them. This agency is achieved incrementally starting with media-enabled, simple, and meaningful interactions, participatory learning, and capacity and skills building or empowerment. At the community or society level, the agency provides its carriers with the power to change and influence both 1) the immediate decision-making process and its outcome through co-creation (e.g., Harris, 2014), and 2) the far-reaching decisions and policies regarding climate change issues through deliberation and political participation (see Carvalho et al., 2017). Dialogic engagement, public deliberation, and political participation will have effects on macro-level decisions, governance, policies, research agendas, but also culture and education. These outcomes in turn will influence the media landscape and the constructs that function at the micro-level such as values, habits, knowledge and skills. Then again, a new cycle in the formation of engagement starts.

The proposed model is primarily a device for understanding the various roles media can have as well as their influence on individual and public engagement. The model can serve also research and design practice functions in that future studies and communication practices can adopt this model to 1. position their contributions, and 2. focus on interventions that address specific goals regarding media and/or engagement stages. Furthermore, future literature reviews and media studies can map existing research and practice according to this model. In this way, the evolution of the research and practice can be described and categorized, and this model can thus be tested as to its practicality and theoretical insight.

7 Conclusion

This paper described a detailed and systematic review of the empirical literature on interactive and participatory media for climate change engagement. Insights from four relevant literature reviews also consolidated the empirical findings. Empirical evidence of the effects of media interactivity and participation on cognitive, emotional, and behavioural engagement and of existing challenges was thoroughly screened and synthesized. A research agenda to fill the gaps in the area of interactive and participatory media was proposed and an integrative model of how media can engage the individual and public with climate change was introduced and described. The research in this area is multi-, inter- and trans-disciplinary and there are also many fields of practice that are involved: media, information systems, visualization and computer science, environmental technology, education. To progress steadily with engaging the public with climate change, researchers and practitioners in the relevant fields should address the challenges and gaps identified in this review and similar reviews. The model of public engagement proposed in the paper could furnish interested stakeholders with a reflective and practical device for research and action towards fighting climate change. One crucial objective for the future is to empower the individuals and the public as collective entity to act with knowledge, skills, and responsibility towards a sustainable world.

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Appendix: Reviewed corpus

Primary empirical studies

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Primary literature review studies

Carvalho, A., van Wessel, M., & Maeseele, P. (2017). Communication practices and political engagement with climate change: A research agenda. *Environmental Communication*, *11*(1), 122-135.

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INTERACT publications:

5. Dorina Rajanen (2021, November) Interactive and participatory media for public engagement with climate change: A systematic literature review and an integrative model.

4. Marianne Kinnula, Netta Iivari, Sumita Sharma, Jussi Okkonen & Sirkku Kotilainen (Eds.) (2020, December) Special Issue on Designing the future of technology with and for children.

3. Mikko Rajanen & Dorina Rajanen (2020, October) Co-creation of a safety culture in digital fabrication: Outcomes and insights from a workshop at the 2019 FabLearn Europe Conference.

2. Karin Väyrynen & Arto Lanamäki (2020, February) Suomen taksamittarisääntelyn monitulkintaisuus.

1. Andrea Botero, Helena Karasti, Joanna Saad-Sulonen, Hanne Cecilie Geirbo, Karen S. Baker, Elena Parmiggiani & Sanna Marttila (2019, March). Drawing together: Infrastructuring and politics for participatory design.