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Invited Review

Advancing disaster risk communications

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ABSTRACT

Effective communication of disaster threats to decision makers and at-risk communities is a growing challenge in a people-centred approach to disaster risk reduction. Traditional communication approaches tend to involve either top-down risk management practices or bottom-up community health and education practices. But an alternative blended approach emerges from the academic realm of science communication.

In practical terms, the science communication lens focuses attention on a trio of practices for DRR: one-way *dissemination* of risk information to a broad public; two-way *dialogues* that identify, engage and consult with specific stakeholders in the risk management process; and three-way *participation* initiatives that enable informed conversations between communities and decision makers and within communities themselves, to motivate action. The strategic intent of communications – whether that be promotion, persuasion or partnership – ought to be guided by a 'theory of change' that delivers clear and coherent DRR goals and by training programmes that recognise the need to integrate a variety of interventions from across the communication continuum.

1. Introduction

Effective disaster risk communication lies at the heart of meaningful disaster risk reduction. It is the oil that lubricates relations between diverse stakeholders and smooths the flow of knowledge and information along the risk decision-making chain. Mis-communication, by contrast, or indeed deliberate spread of dis-information, is widely seen as a barrier to science being 'useful, usable and used' and a pervasive bottleneck in disaster risk governance endeavours (Aitsi-Selmi et al., 2016a). Carefully considered efforts are needed, therefore, to convey informed knowledge on disaster impacts to both decision makers and those directly at risk (Ismail-Zadeh et al., 2017). Yet, despite the widespread emphasis on disaster planning and foresight, risk communication remains frequently a knot at the tail end of that process rather than being threaded throughout (Fakhruddin et al., 2020).

There are encouraging signs, however, that the central importance of communication is gaining acceptance in the disaster risk community (Fakhruddin et al., 2020). For the first time, the latest UN Office for Disaster Risk Reduction's state-of the science Global Assessment Report (GAR) has included a chapter on risk communication (UNDRR, 2022). Moreover, two of three key priority action areas identified in GAR 2022 relate to communication. The first - to 'design systems to factor in how human minds make decisions about risk' - recognises the role of people's perceptions of risk and biases to close the gap between intention and action. The second - to 'work across silos and design in consultation with affected people' - embraces a 'risk language' that cuts across multiple disciplines and enhances participation, transparency and citizen dialogue.

This pair of priorities have different roots. The first is a largely top-down approach favoured by risk authorities. It draws from the 'hard' empirical science of risk perception, analysis and management, which since the 1980s has been deriving cognitive and behavioural psychology insights, with a focus on the individual, to inform strategic corporate and political communications (Tversky and Kahneman, 1985; Kasperson et al., 1988; Kahneman, 2011; Meyer and Kunreuther, 2017; Yamori, 2020; Balog-Way et al., 2020). The second is a typically more bottom-up, community-based approach favoured by those working in field-based development studies and public health education (Burke, 1999; Wisner et al., 2012; López-Carresi et al., 2014; Mehta et al., 2016), borrowing methodologies from the social sciences and humanities (Donovan et al., 2019).

Current disaster risk communication endeavours, therefore, tend to be polarised around these two contrasting, and potentially conflicting, risk perspectives (Fig. 1). This polarisation underlines the challenge of the 2015–2030 UN Sendai Framework's ambition to integrate conventional top-down, expert-driven risk reduction approaches with emergent

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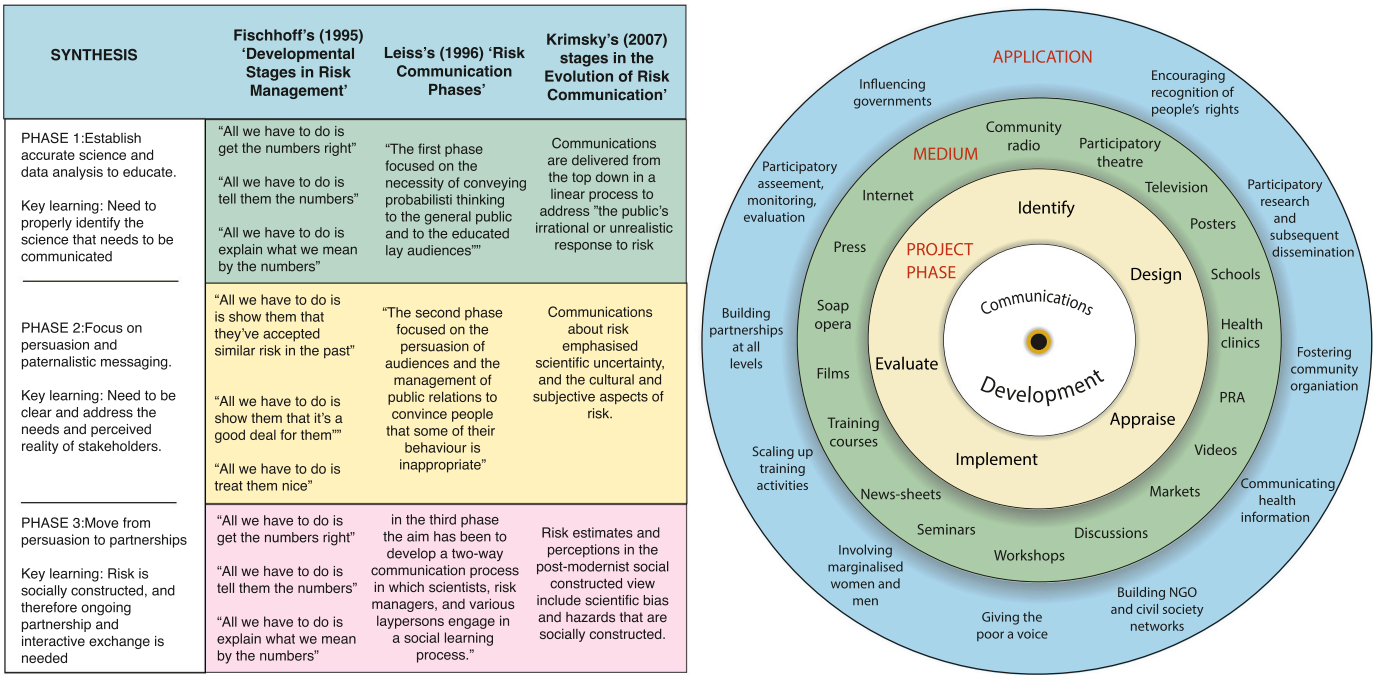


Fig. 1. Contrasting perspectives on risk communication: (Left) communications viewed through a risk management lens (from (O'Connor et al., 2015)). Right: communications viewed through a development lens (Burke, 1999).

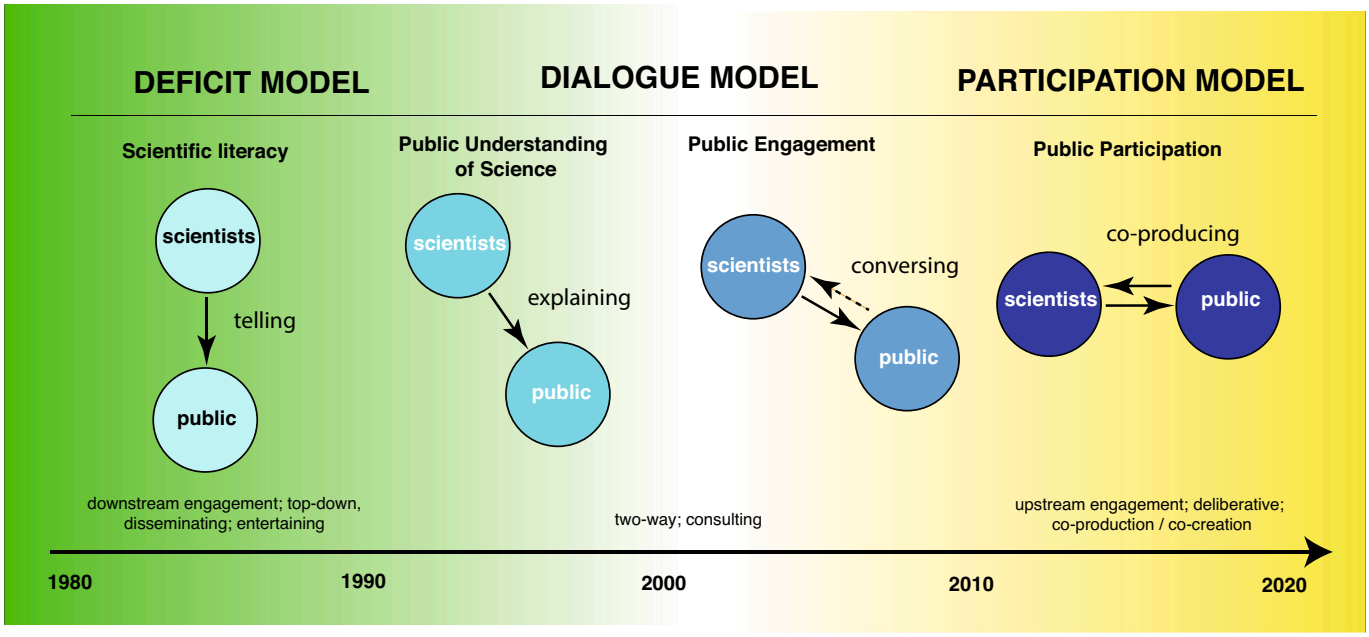


Fig. 2. Schematic summary of the evolving history of science communication.

bottom-up, people-centred approaches (UNISDR, 2015). In bridging that divide, a possible mediating perspective comes from a third, contemporaneous field of inquiry: science communication.

For four decades, the discipline of science communication has been growing as an area of research and outreach within academia (Brake and Weitkamp, 2009; Bowater and Yeoman, 2012; Cormick, 2019; Besley and Dudo, 2022), establishing a diverse portfolio of principles and practices for science-society engagement (Besley and Tanner, 2011; Besley et al., 2015). The result is the emergence of three consequent and overlapping modes of intervention that might be usefully applied to the disaster risk reduction arena: dissemination, dialogue and participation (Stewart et al., 2023).

2. Science communication models and constructs

2.1. *Deficit*

Although the popularization of scientific inquiry is a long-standing tradition, public communication of science gained academic standing in the 1980's with the push for a better scientific 'literacy' amongst citizens (Miller, 1983) (Fig. 2). A perceived lack of 'public understanding of science' was inferred by scientific authorities to explain why many

citizens adopted behaviours or views that were inconsistent with 'sound science' (Bodmer, 1985; Durant et al., 1989; Ziman, 1992). Under this so-called 'deficit model' (Wynne, 1991; Ziman, 1991), the purpose of the scientist communicator was to better convey scientific knowledge and understanding to those deemed to need it most. By promoting information in a rational and objective manner, experts contended, ignorance would be reduced and the views and actions of public audiences would 'follow the science' (Bubela et al., 2009). Since most adults encountered science through media coverage, the fledgling field of science communication was closely bound to the tenets of science journalism and moulded on the wider print and broadcast media landscape (Weigold, 2001).

Within a decade, however, the deficit-oriented mindset was being deeply questioned, not least because it maintained a one-way, top-down, science-centered approach (Gregory and Miller, 1998; Trench, 2008) …

> "… in which scientists—with all the required information—filled the knowledge vacuum in the scientifically illiterate general public as they saw fit. There was a flow of knowledge, from the 'pure' source of science in the laboratory to a (somewhat tainted) Bowdlerised variety that was fit for public consumption and was usually disseminated through the mass media. The scientific community was most definitely in control of this flow. Scientific facts and methods were the vital components of public understanding for the deficit model."
>
> (Miller, 2001, p116)

2.2. Dialogue

By the early 1990s, a more reflective approach was emerging in which the focus was less on what audiences did not know and more on what they did know and on their subsequent questions and concerns (Fig. 2). It was a shift that acknowledged the social construction of science (Latour, 1987) and the importance of social context and lay knowledge in shaping how science was used by the public (Irwin, 1995; Wynne, 1995). It recognized that whilst scientists had scientific facts at their disposal, the public had local or situational knowledge and personal investment in the problems to be solved (Miller, 2001).

In this approach, dialogue offered the alternative to dissemination (Bucchi and Trench, 2016). The purpose of science communication became less about conveying 'matters of fact' and more about conversing about 'matters of concern' as the strategic intent shifted from 'educating' the public to 'engaging' them in debate and discussion (Kleinman et al., 2011; Dietz, 2013; Rowe and Frewer, 2005). 'Public understanding of science' was recast as scientific understanding of the public, founded on a growing body of empirical research that showed that public (mis)understanding of science was more complex than simply a deficit of knowledge (Sturgis and Allum, 2004).

The new 'dialogue model' drew its intellectual vigour from the social and cognitive sciences (Trench, 2008; Brossard, 2009; Nisbet and Scheufele, 2009). Social psychology studies revealed how people rarely make decisions based only on scientific information, instead drawing on their own goals and needs, knowledge and skills, and values and beliefs (Scheufele, 2013). So, even if people could grasp the scientific ideas that the experts wanted them to know, for diverse reasons they still might not agree or act consistently with the scientific consensus. Social cues and cognitive shortcuts were identified that better resolved how people accepted or rejected scientific information. Media amplification or distortion of risk messages meant it was important to understand how public opinion could be manipulated (Kasperson et al., 1988), particularly through political malice via the internet and social media (Scheufele, 2013). Audience perceptions, public attitudes and media representations could be analysed through social research methods, thereby guiding how scientific messages might be better tailored for and targeted at specific audiences.

By the early 2010s, a robust 'science of science communication' was firmly established (Fischhoff, 2013; Jamieson et al., 2017). Its principles and practices - multi-disciplinary but rooted in human science - advocated for an evidence-based science communications that built on the rich stockpile of empirical good practice about 'what worked' (NAS, 2017).

It was an approach not without its critics. The need for science-society dialogues to embrace more multi-cultural and multi-lingual audiences contrasted with a behavioural science evidence base largely tried and tested in North America, Europe and Australasia (Bucchi and Trench, 2021). Moreover, the emphasis on more rigorously tuned scientific messaging tends to enhance mainstream, expert-driven narratives. Given the power imbalance between scientists and the public, these could be considered paternalistic and overly manipulative, potentially closing down, rather than opening up, public science conversations. After all…

> "…dialogue is not about reaching consensus, but about learning with and from each other. In that sense, public dialogues can be seen as opportunities to bring science closer to society; to improve relations; and to demonstrate that scientists do care."
>
> (Reincke et al., 2020, p.3)

2.3. Participation

In recent years, science communication praxis has become less about conveying findings and stabilized, 'finished' knowledge and, instead, more about stimulating diverse and disparate publics to think about, respond to, and discuss science and its role in society. The rise of public engagement has unleashed a rich variety of science-society interactions in which lay audiences are active participants. The broad aim, to the extent that there is one at all, is to motivate 'a social conversation around science' (Trench, 2008; Bucchi and Trench, 2016; Bucchi and Trench, 2021), not just between the public and scientists but also amongst the public themselves.

> 'If deficit and related modes of communication can be considered one-way, and dialogue two-way, then participation can be represented as three-way, because it implies publics or citizens talking with each other as well as talking back to science and its institutions.'
>
> (Bucchi and Trench, 2016, p.158.)

The push for multi-directional and cross-sectoral conversations has opened up new spaces in which multiple publics can contribute a wide range of views on research priorities and science policy (Bubela et al., 2009). In some cases, this literally can be new social spaces – cafes, bars, art galleries – where novel science-infused activities can reach different audiences (Whitmee et al., 2020). In other cases, it can be new deliberative spaces, such as consensus conferences, citizen juries and citizen assemblies (Devaney et al., 2020; Muradova et al., 2020). It is an approach rooted in a deeper form of engagement associated with broader ideas of participatory democracy, social learning and co-production (Rowe and Frewer, 2000, 2005).

This 'participation model' pluralises the range and relevance of views and stakeholders. It 'opens up' public and policy options and challenges the political use of existing science. Communication becomes part of a collective and continuous *process* of knowledge production rather than the final act of knowledge transfer. That process is advanced by practitioners skilled in facilitation, negotiation and conciliation because there are always individuals or groups that oppose the information flow and push their own objectives. The discourse is socially contested explicitly because it is rooted in people's varied everyday concerns. However, its effectiveness need not be judged on the degree to which people's decisions ultimately align with the science:

> "Ideas, information or images from and about science can spread widely, as one conversation opens another: in the process, the ideas,

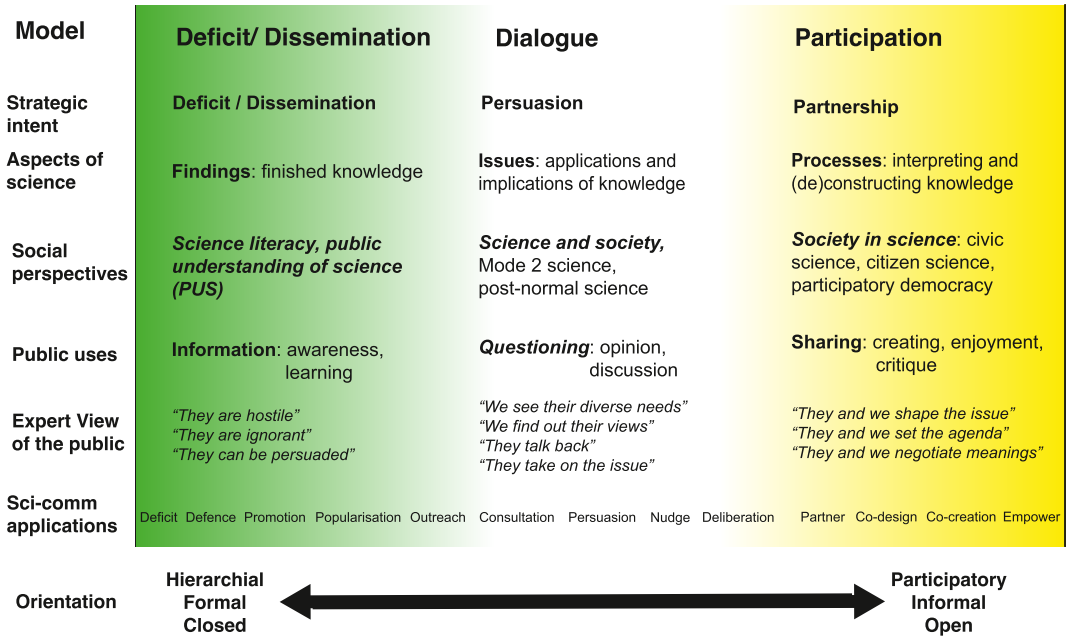


Fig. 4: Simplified schema of science communication perspectives, uses and applications (redrawn from [38, Table 1] and [50, fig. 1).

Fig. 3. Simplified schema of science communication perspectives, uses and applications (redrawn from (Bucchi and Trench, 2016, Table 1) and (Bucchi and Trench, 2021, Fig. 1).

> information and images inevitably acquire new meanings. This process does not always or only depart from and return to science, its actors and its institutions; it swirls in society somewhat independently, and with interruptions, and that is what we intend to capture with the preposition, around, in our definition of science communication as the social conversation around science.
>
> *(Bucchi and Trench, 2021, p. 7)*

3. From science communication to disaster risk communication

Over the course of a few decades, science communication has evolved through a succession of conceptual frameworks, from closed unidirectional messaging, through mediated bilateral exchanges, to engaged and deliberative multi-directional conversations (Bucchi and Trench, 2021) (Fig. 3). Yet despite this appearance of a temporal progression - from dissemination through dialogue to participation - all three modes of science communication remain prevalent amongst practitioners. In particular, the initial 'deficit model' thinking may have been discredited by communication professionals but it remains deeply resonant (Renn, 2014; Suldovsky, 2016). Moreover, it continues to underpin the way that many scientists seek to communicate (Besley et al., 2015; Davies, 2008; Dudo and Besley, 2016). Indeed, this tends to be the default mode in the traditional top-down approach of 'command-and-control' disaster risk management by which information exchanged between scientific experts and risk authorities is relayed to the public (Fig. 4a) (Scolobig et al., 2015). Although there might be contacts between the experts and the wider public, these tend to be casual, with no expectation or mechanism for a return flow of knowledge. In contrast to such well-entrenched one-way communications, the 'people-centred' approach of the UN Sendai Framework advocates for two-way exchanges between risk authorities and at-risk publics to prompt informed conversations that enhance risk governance and develop trust (Fig. 4b). But there is also a need for 'three-way communications' - informed conversations *amongst* stakeholder groups - to generate problem solving and motivate action. (Fig. 4c).

In the following section, the key attributes of a continuum between one-way, two-way, and three-way communications are examined in the context of disaster risk reduction ambitions (Fig. 5).

4. One-way disaster risk communications: dissemination

When hazardous events strike, the clear, unambiguous and unidirectional flow of information from authorities to the public about how to avoid harm is critical. In such sudden-onset crises, one-way instructional communications – alerts, warnings, situational information, evacuation details – form a core part of actionable risk messages (Wood et al., 2012). Although 'crisis communications' is distinct from 'risk communications' (Table 1), a common shared challenge is the need to convey concise, brief and clear messages backed up by supporting facts and proofs (Covello, 2006).

In preparing for disasters, risk authorities often apply a similar top-down, expert-driven and message-centred approach adopted in emergency crises. It is, by and large, a deficit-model approach designed to pass on acquired technical knowledge to at-risk groups that are not aware of it (and may not have asked for it, nor indeed see the need for it). Here, the public's perceived risk knowledge deficit is typically regarded as the critical barrier or problem to be overcome. Consequently, the inferred solution to that perceived problem is for the scientific expert to become a better communicator.

To address this challenge, communication training by media professionals can provide technical specialists with practical guidance on how to present complex information in accessible ways, offer insights into how to engage different audiences, and provide hands-on experience in working with journalists and the wider media. The core communication challenge is how to convey dry and complex technical information in simpler and more imaginative ways. Specialists have conventionally conveyed hazard and risk information using traditional media products, such as news articles, infographics, webpages, bulletins, and public presentations, but with the rise of new social media more and more hazard and risk information is being disseminated via social media platforms and smartphone apps (Alexander, 2014; Khanal et al., 2022). Supported by communication training and media professionals, scientific experts increasingly design and create their own informational content and distribute it directly to end-user audiences.

With the emergence of the new internet-based media landscape,

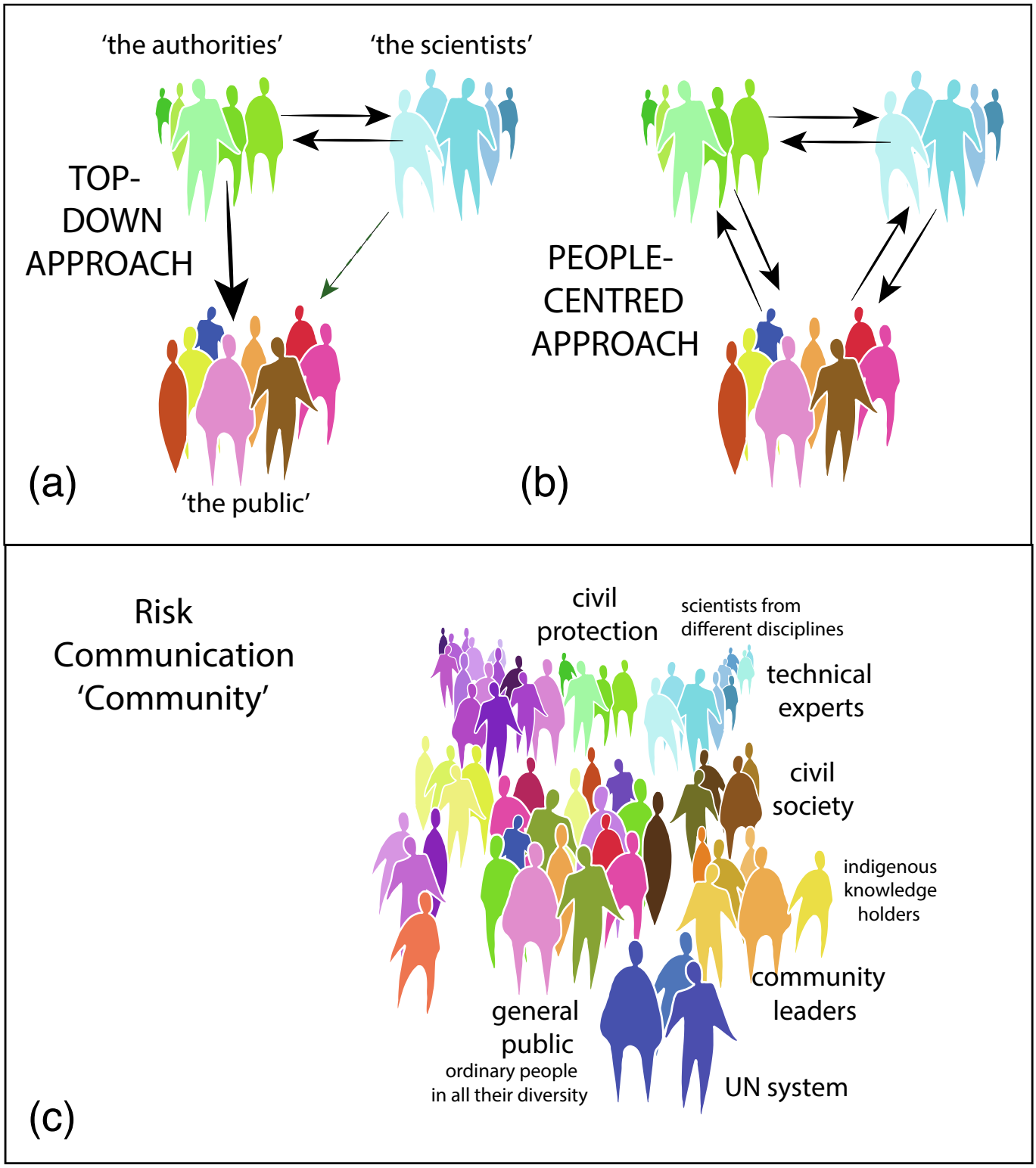


Fig. 4. A simplified depiction contrasting (a) largely one-way communications in a conventional top-down, expert-led risk management approach and (b) largely two-way communications in a people-centred risk management approach (adapted from Scolobig et al., 2015). In reality, risk communications community comprises a diverse 'ecosystem' of stakeholders in which three-way risk conversations need to take place (c).

digital technologies are becoming the main way to disseminate 'more targeted and actionable risk information to diverse audiences across multi-cultural, multi- disciplinary and multi-jurisdictional boundaries' (Boersma et al., 2017, p. 392). Most visual representations of hazard and risk have largely been used as educational tools to improve knowledge for critical target audiences (e.g. Dengler, 2005), but the benefits of visual media extend beyond awareness raising (Downs, 2014; Solinska-Nowak et al., 2018). Films and videos can help to convey information or processes that are perhaps hard to envision or understand, to influence perceptions, to motivate behaviour change, to increase trust, and to maintain the social memory of particular events (Suarez et al., 2005; Hicks et al., 2017). More recently, "serious games" – video and physical

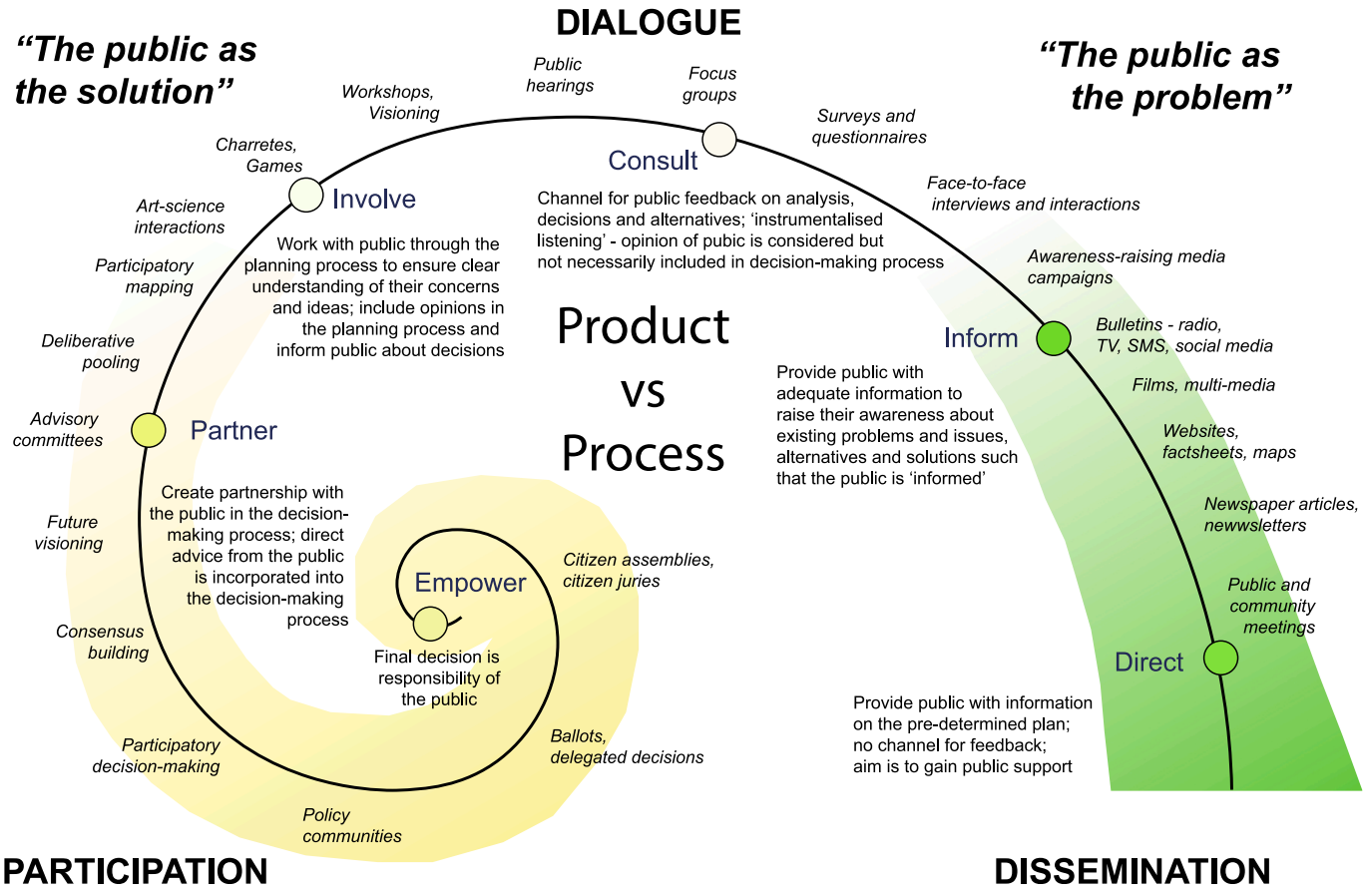


Fig. 5. The process of public engagement as a continuum of communication practices reflecting changing intent – dissemination (green), dialogue (white) and participation (yellow). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Distinguishing features of risk communication and crisis communication (from Reynolds and Seeger, 2005, cited in Sellnow and Seeger, 2021).

Risk Communication	Crisis Communication
Risk centred: projection about some harm occurring at some future date	Event centred: Specific incident that has occurred and produced harm
Messages regarding known probabilities of negative consequences and how they may be reduced	Messages regarding current state or conditions: Magnitude, immediacy, duration, control/ remediation, cause, blame, consequences
Based on what is currently known	Based on what is known and what is not known
Long-term (pre-crisis stage) message preparation (i.e. campaigns)	Short term (crisis stage) – less preparation (i.e. responsive)
Technical experts, scientists	Authority figure, emergency managers, technical experts
Personal scope	Community or regional scope
Mediated: Commercials, ads, brochures, pamphlets	Mediated: Press conferences, press releases, speeches, websites
Controlled and structured	Spontaneous and reactive

games in which the primary purpose is not pure entertainment – offer powerful tools to convey the visceral impacts of otherwise abstract disaster threats and influence people to adopt in risk-reducing measures (Mani et al., 2016; Gampell et al., 2017; Gampell and Gaillard, 2016; Solinska-Nowak et al., 2018; Macchione et al., 2019; Mol et al., 2022; Khanal et al., 2022; Twomlow et al., 2022).

Whatever the mode of communication, a critical way to ensure one-way risk communication resonate with external audiences is to convey dry, abstract technical information as stories (Stewart and Nield, 2013). The narrative formats of stories offer increased comprehension, interest, and engagement, even for complex ideas (Dahlstrom, 2014). They help people to connect personally and emotionally with ideas and information that may otherwise be mundane, complex and remote (UNDRR, 2022). Indeed, they are intrinsically persuasive, offering tactics for winning over otherwise resistant audiences. Moreover, in practical terms the use of narratives also reflects the everyday reality that non-experts get most of their science information from the mass media, which is itself constructed around stories (Dahlstrom, 2014).

Although story-telling has always been a core element of journalistic and popular media approaches to communicating hazard and risk, narrative-driven approaches are now being adopted by expert practitioners to convey high-uncertainty threats. Conventional risk communication typically portrays the likelihood of an event using model-based probabilistic projections, which are not only technically complex but also are notoriously difficult to convey to non-experts (Gigerenzer et al., 2005; Stephens et al., 2012). In risk decision making, when knowledge is uncertain, experts are encouraged to resist the pressure (or temptation) to over-simplify the situation by framing their information in a "single, definitive" form (Stirling, 2010). Instead, they ought to frame their available information in a "plural, conditional" form (scenarios) in order to adequately reflect and convey the complexity of the situation. Event-based storylines – scenarios which explore plausibility rather than probability - are common practice in 'stress testing' emergency preparedness in crisis management, but are now being applied to the challenges of climate and disaster risk (Davies et al., 2015; De Bruijn et al., 2016; Shepherd et al., 2018; Shepherd, 2019; Sillmann et al., 2021). Similarly, revisionist narratives of past events – alternative realities about how actual risk events might have turned out worse – provide compelling *counterfactual* perspectives on the nature of hard-to-

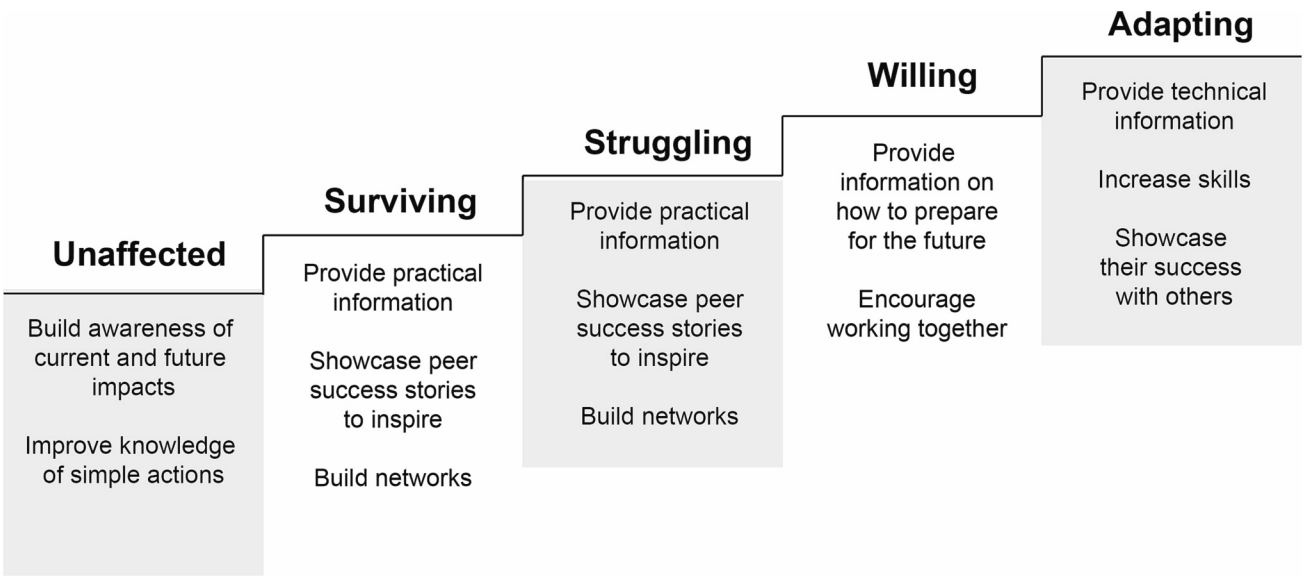


Fig. 6. Different demographic segments ('unaffected', 'surviving', 'struggling', 'willing', 'adapting') have different communication needs, and consequently require different engagement strategies. From Whitehead (2017).

grasp compound risk threats (Woo, 2019).

Descriptive 'storylines' of plausible events in the past or the future provide potentially powerful ways to disentangle the key drivers of risk, and their interaction. Storylining allows risk experts to represent multiple and alternative outcomes, navigate high uncertainty, and link disparate kinds of evidence. An essential ingredient in human decision-making is the emotional ('affective') connection that stories provide. They allow at-risk publics take in, make sense of, and make use of technical knowledge because: (1) dramatization, which describes an event in vivid terms, makes it more tangible and realistic to the audience; (2) narratives that are contextualized and personalized offer messages that speak more directly to people and to their situation; and (3) risk messages that are framed in ways that everyone can re-tell can be more easily shared across the community (Lejano et al. (2021).

In summary, the design principles of stories and storylines ought to be an integral part of risk communications training; 'experts and agency representatives need to privilege narrative, and gain skills in translating technical knowledge into this form' (Lejano et al., 2021, p.7). But storifying risk to raise public awareness is only a first step in disaster preparedness. Engaging and instructive risk stories offer essential 'conversation starters' for individuals, households and communities to talk about hazard threats. An important end goal of risk dissemination, therefore, is to promote risk dialogue.

5. Two-way DRR communications: dialogue

The underpinning logic of many disaster risk communication programmes is that improving people's awareness of hazard threats will motivate action, but the empirical evidence indicates that this premise is unfounded (Harries, 2008; Lindell et al., 2009; Solberg et al., 2010; Paton, 2019). Instead, it is deeper social and psychological processes that influence whether, and to what extent, people actively prepare for disasters. To resolve those processes requires risk practitioners to have a more nuanced understanding of the public they are trying to reach.

By appreciating who their intended public is, and what their concerns are, risk specialists can better tailor and target their communication products and practices (Verrucci et al., 2016). That means investing in 'audience segmentation' research – ranging from key informant interviews and focus groups to social media analytics - to find out what matters to people in their lives and the everyday contexts in which they make risk decisions (Abraham-Dowsing et al., 2014). It is a practice widely used in the area of climate risk (Hine et al., 2014; Hine et al., 2016; Metag and Schäfer, 2018; Detenber and Rosenthal, 2020) but increasingly also in the disaster risk domain (Adams et al., 2017; Daellenbach et al., 2018; Kim and Madison, 2020; Bartolucci et al., 2023).

A practical example of this approach is provided by BBC Media Action's communication efforts in Bangladesh and Tanzania to support people's resilience to climatic and environmental shocks (Whitehead, 2017). Based on extensive interviews, the target audiences in both countries were segmented into five groups with different distinguishing characteristics in terms of their stages of action (surviving, struggling, adapting, willing and unaffected). Each segment group had distinct communication needs, which required addressing through contrasting communication interventions (Fig. 6.).

The case study highlights how different 'publics' requires distinct engagement strategies to 'frame' information in ways that are accessible and salient (Bubela et al., 2009; Scheufele, 2013; Nisbet, 2015; Druckman and Lupia, 2017). Appreciating the importance of framing, and understanding the ways that people perceive and process risk information, is at the heart of risk communication practice (Balog-Way et al., 2020). Misjudging the intended audience means that even well-intentioned disaster management messaging not only can produce an undesirable public reaction, but might possibly solidify public sentiment to resist or deny that very message (Wood and Miller, 2021; UNDRR, 2022).

Despite a wealth of studies on how people process information, human action or inaction is not driven solely by conscious, rational decision-making carried out by individuals (Joffe, 2003; Joffe and O'Connor, 2013; Joffe et al., 2013). For that reason, the last decade or so has seen a shift from an almost exclusive focus on cognitive science to a growing appreciation of the role played by socio-cultural and emotional factors in driving risk behaviour (Slovic, 2010).

> "When 'risk perception' is approached in this way, we see that the public's assessments of potential dangers do not differ from those of experts purely because they cannot do the sums. Rather, they care about different things: people's representations of risk are not solely based on evaluations of probability and severity, but incorporate a wide range of relevant information about the personal, community and societal contexts in which the disaster would occur."
>
> (Joffe and O'Connor, 2013, p.14)

This shift to social representation of disaster threats places increased

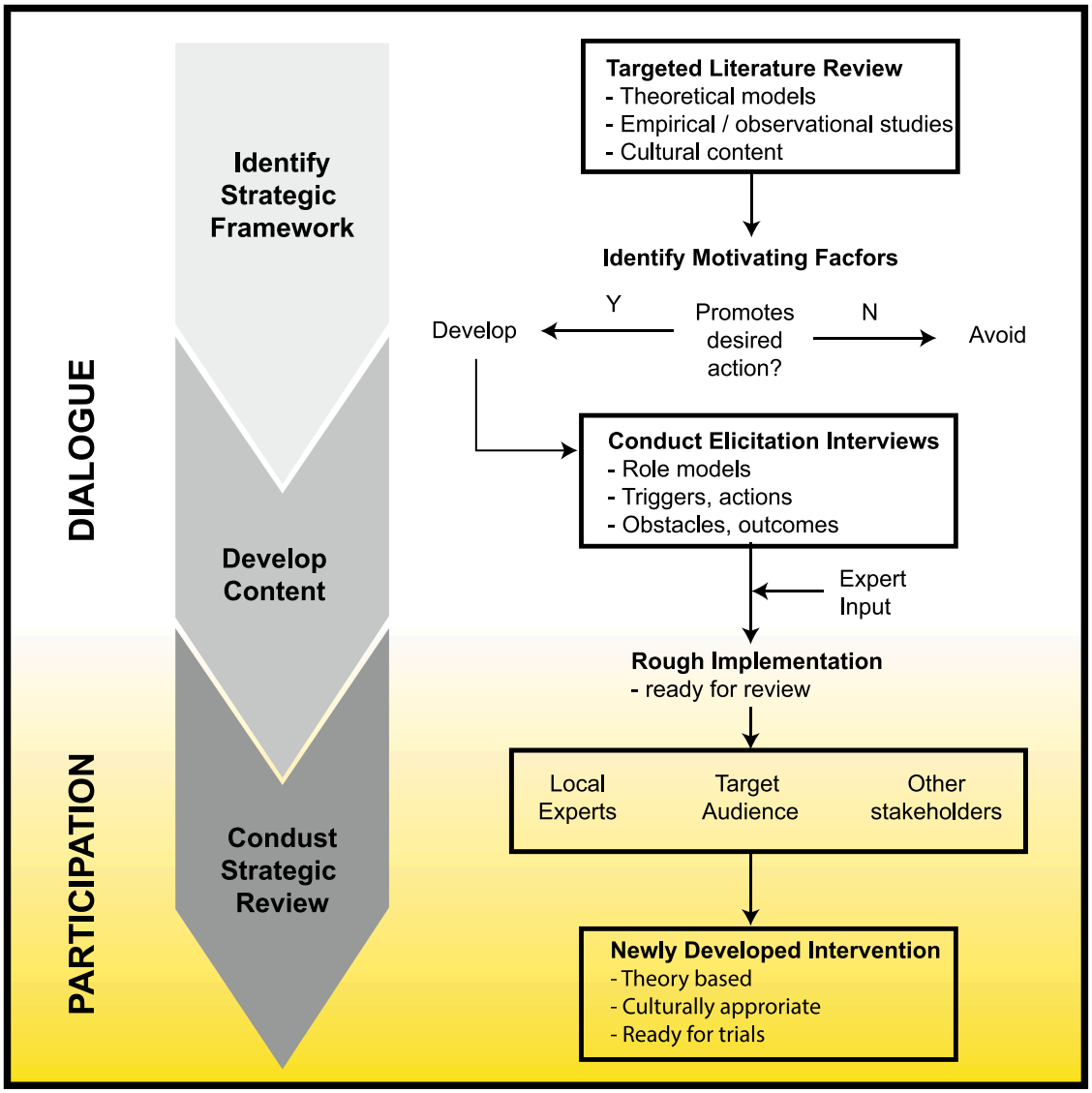


Fig. 7. An example of a theory-based communication intervention (From Sanquini et al., 2016, Fig. 1), highlighting how an understanding of socio-cognitive factors that typically motivate (e.g. knowledge, self-efficacy and effectiveness) or demotivate (e.g. fear, fatalism) desired action can help inform locally-grounded communication interventions, which can be reviewed and appraised with target audiences and other local stakeholders.

significance on the public's knowledge of their own risk landscape. Local, contextual knowledge tends to be poorly valued in risk management approaches, often being viewed merely as situational information to be passed on to experts (Lejano et al., 2021). But local knowledge are also ways of seeing and observing that are unique to each culture, and serves as a lens through which local communities will view risk information (Ali et al., 2021). In that regard, communities themselves are likely to be rich repositories of wisdom about the threats that confront them (Wisner et al., 2012).

An example of how this approach might be applied in a disaster risk communication context is provided by an earthquake education initiative in Nepal (Sanquini et al., 2016). The community film project was underpinned by a three-stage process that built on a strategic grasp of the theoretical framework and cultural context, storified local knowledge based on interviews with community members, and evaluated effectiveness through a critical review of the finished film by key stakeholders (Fig. 7). The film deliberately cast community members to dramatize the real lives of residents from poor backgrounds in recognizable settings who had taken actions that contributed to earthquake-resistant schools. The film dramatised multiple local narratives of becoming aware of risk, deciding to take action, overcoming barriers and achieving what was set out to do, emphasising self-efficacy through both dialogue and images. Follow-up analysis showed that viewers who watched the film were statistically more likely to have: higher knowledge of earthquake-resistant construction design, materials and methods; confidence in efficacy of such construction items; intention to support such construction; and intention to recommend building earthquake-resistant homes to others.

In summary, involving individuals, households and communities in risk dialogues spans a continuum, ranging from an instrumentalized analysis of the intended audience (to allow expert-driven messaging to be better targeted) to a more inclusive and authentic engagement of the at-risk public in the communication process. In this way, risk conversations emerge as key motivators for the active involvement of people in their own risk reduction efforts, potentially addressing a persistent deficiency in conventional disaster risk communication interventions:

> "Despite decades of progress in disaster risk reduction, efforts to enhance risk awareness and influence behavioral change still seem to be falling short. When we reflect on our collective experience and envision the future of disaster risk reduction programs, we find

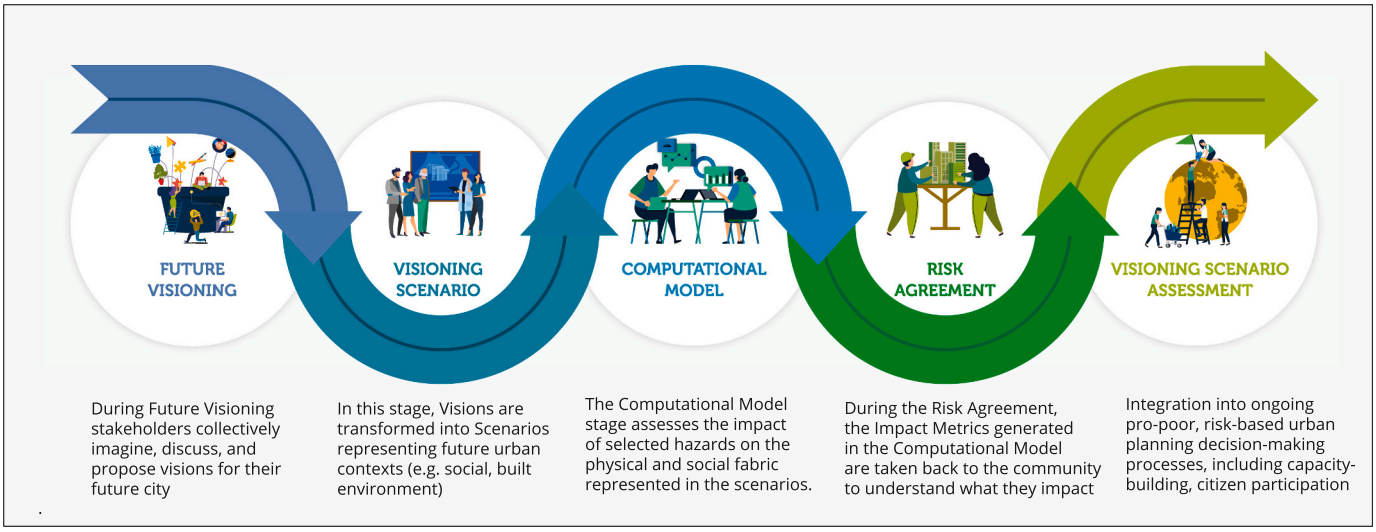


Fig. 8. A workflow for the Tomorrow's Cities urban disaster risk project showing how the development of hazard analysis based on vision scenarios co-produced with and validated by local stakeholders. (Source: tomorrowscities.org).

promise in approaches that implicitly treat knowledge as not just something transmitted but as a relationship fostered with multiple publics. In this mode, the public is not simply a passive recipient of expert knowledge but a co-producer of risk knowledge."

(Lejano et al., 2021, p.1)

6. Three-way DRR communications: participation

Communities on the ground may be the 'last mile' in the risk communication chain, but they are the first line of defence in facing disasters (Aitsi-Selmi et al., 2016b). A recognition that those on the risk frontline have capacities - knowledge, skills, and resources – to mitigate disaster impacts, has led increasingly to the rise of community-centred disaster risk reduction, which aims to actively engage local communities in assessing and addressing disaster threats (Luna, 2014).

Art-science initiatives offer one way to encourage people to think about disaster risk and resilience in ways that science, data, and numbers cannot. Poetry, painting, puppetry, photography, music, songs, dance and street theatre can all tell stories across cultural barriers, building empathy for communities who are facing increased risk (Petal and Izadkhah, 2008; West et al., 2019; Sutton et al., 2021). Emotions evoked by artistic practice can convey a sense of urgency for preventing and preparing for disasters, whilst their aftermaths are often times of creative outpourings (Casacchia et al., 2012). In post-disaster settings, communications can variously be part of the healing exercise, a way to gather insights into what worked and what went wrong, or explorations about future pathways for community recovery and renewal (Seeger, and Sellnow., T.L., 2016).

But although art-science collaborations have gained prominence in the climate change arena (Yusoff and Gabrys, 2011; Dal Farra and Suarez, 2014; Kruczkiewicz, 2018; Cosgrave and Kelman, 2017), their effectiveness as communication tools remains uncertain (Hahn and Berkers, 2021). If they are to be effective in shaping risk perceptions and behaviours, they need to be carefully choreographed as part of a wider communications plan:

"… creativity alone – in the absence of a robust strategy rooted in a deep understanding of people's realities and how they make decisions – might result in an entertaining or intriguing experience but fall short of prompting meaningful shifts in how people think, feel or act on risk… Risk communication initiatives that blend physical science, social science, strategic planning, and creativity into outputs targeting clear goals and objectives are likely to have the most impact."

(UNDRR, 2022, p132)

Another approach to widening public participation in disaster risk conversations has been through 'citizen science' (Bonney et al., 2014, 2016. Fraisl et al., 2022). Such initiatives can be limited to simply co-opting people as amateur observers or passive recorders to provide data to experts, with no direct benefits to themselves. But genuinely participatory citizen science extends to engagements that can bend scientific concerns to local needs, thereby empowering people to action (Irwin, 1995). There is an extensive academic literature and body of praxis around the mechanisms of empowerment – both individual and collective - and the processes and structures of public participation (e.g. Rich et al., 1995). In the context of disaster risk, citizen science blends with participatory DRR approaches in supporting people develop their own long-term, sustainable mitigation strategies, as well as drawing them and their communities into the formal risk decision-making processes (Hicks et al., 2019). In this context, citizen science is about knowledge making at its broadest, fostering an informal culture of prevention amongst at-risk publics.

The principles and practices of participatory DRR are complex and contested (Reid et al., 2009; Cadag and Gaillard, 2012). An enduring challenge centres on ensuring equitable partnerships and authentic empowerment (Hicks et al., 2019). Equity and authenticity can be undermined by insufficient allocation of resources at the local level, and by a lack of willingness amongst the public to share responsibility with authorities for disaster risk management, which can create situations of conflict between public and private interests (Scolobig et al., 2015; UNDRR, 2022).

Crucially, the practitioner skillsets that underpin participatory (three-way) communications are very different to those that underpin one-way and two-way communications. Here, the essential competencies are of facilitation, negotiation and conciliation, building on a host of so-called interpersonal 'soft-skills' (empathy, listening). Specialist input again may come from the social sciences, but it is equally likely to emerge from community-centred health education and development sectors and from the creative arts.

In the disaster risk context, there are increasing examples of emerging good practice in inclusive, people-centred approaches as advocated by the Sendai Framework for Disaster Risk Reduction (Azad et al., 2019; Wolff, 2021; Few et al., 2022). One holistic approach that has emerged from the *Tomorrow's Cities* urban disaster risk hub (Galasso

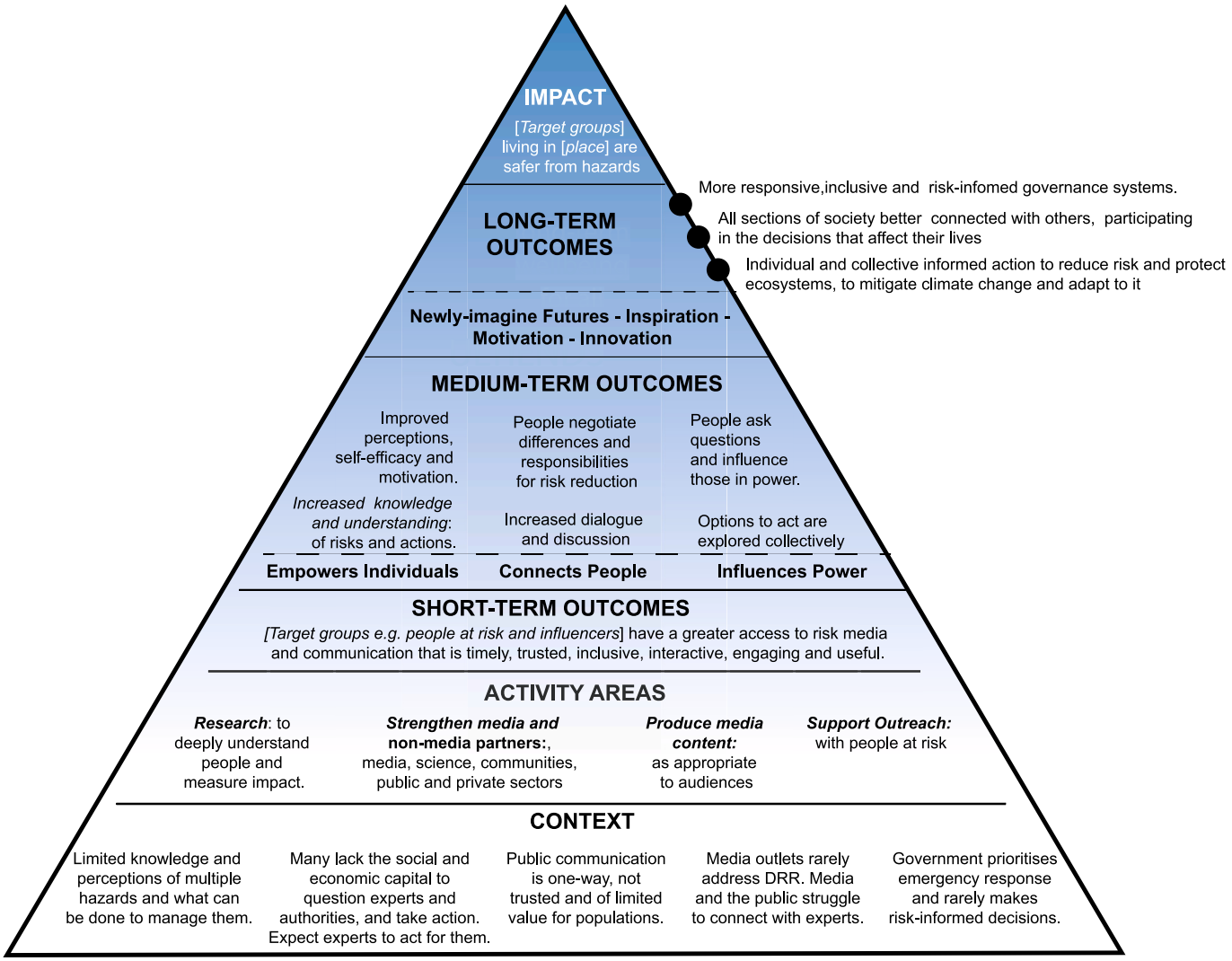


Fig. 9. An idealized "theory of change" for risk communication on disaster and climate change, highlighting the context within which communication is undertaken, the activity areas that are developed, and the short-, medium- and long-term outcomes that are expected to result. Redrawn from (UNDRR, 2022, Fig. 9.1).

et al., 2021) in which a 'decision support environment' involves the interdisciplinary integration of physical and social scientists and risk practitioners (Filippi et al., 2023) underpinned by direct stakeholder engagement (Cremen et al., 2023). This twinned-approach facilitates the co-production of people-centred risk decision making through the development of risk-sensitive 'future visioning scenarios', consisting of urban plans and policies owned not only by planning authorities, municipalities, the government or the private sector, but also by the at-risk communities themselves (Fig. 8).

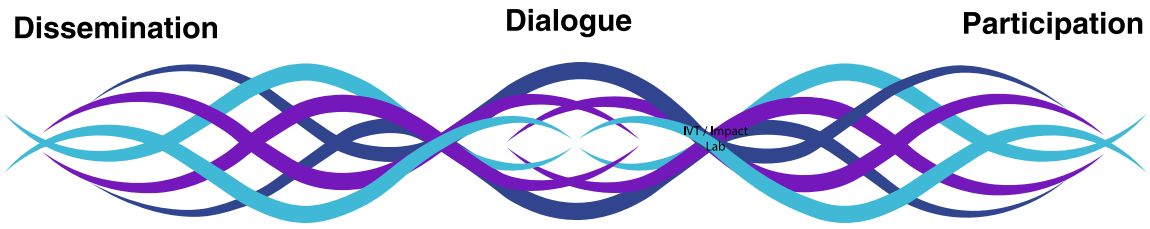
7. Future directions

Effective disaster risk communications are those that help deliver strategic risk reduction goals, so the purpose of the communication – its transformative intent - is critical. For that reason, disaster risk reduction projects ought to be carefully designed, coherent communication strategies, but often they lack a purposeful framework – a 'theory of change' - by which communication will help translate risk knowledge into meaningful impact 'on the ground' (Fig. 9).

> "Too often strategies (if strategies exist at all) are based on vague or undefined objectives such as 'education' or 'awareness raising'. This fails to reflect pathways to change for different groups, compared with taking a dialogue-based approach based on understanding factors such as different types of knowledge, world views and cultures, psychological, social, economic and political systems that influence power, capacity to act and decision-making."
>
> (UNDRR, 2022, p.129)

In developing these strategies, an important question is: what will success look like? In other words, are DRR communications really effective in 'reducing risk'. In a systematic review of risk communication interventions for the mitigation of, preparedness for, response to, and recovery from disasters, Bradley et al. (2016) concluded that some disaster mitigation and preparedness interventions appeared to improve knowledge and behaviour relating to disaster risks. However, the meta-review found that there was little robust evidence of the effectiveness of risk communication for disaster knowledge, behaviour and health outcomes in the response and recovery phases of disasters. Indeed, across the DRR field there is rarely any systematic evaluation of the efficacy of intervention measures within disaster risk communication projects. It is a challenge highlighted in the recent UNDRR GAP report:

> "Knowing if risk communication is making a difference and meeting goals is critical to all stakeholders. Evaluation is part of good practice, demonstrating value for money and justifying funding. Unfortunately, evaluations are often not thought about until the end of projects when budgets are limited, timelines are tight and



make and sell your science	*sense and respond to your audience*	*guide and co-create solutions*
WORKING ASSUMPTIONS		
a lack of information or understanding of science explains why people don't accept scientific claims ('Deficit model')	people rarely make decisions soley on scientific information; they typically take account of their own goals and needs, knowledge and skills, values and beliefs.	social conversations around science need to be embedded in everyday matters of concern
if science communication was done ' better', people would make choices more consistent with the science	there is an empirical evidence base on what makes effective communication	the best sustainable solutions are those co-created with beneficiaries
GOALS		
to promote,excite and entertain about science	to persuade opinions, influence behaviour and shape policy preferences	build and sustain trust among stakeholders to find common ground for decision making
to convey the scientific method and how scientists work	to secure informed consent / overcome opposition among stakeholders	open up policy options with a pluralised knowledge base
to educate and raise awareness of a specific scientific issue	to consult with diverse groups so that multiple perspectives can inform decision making	empower stakeholder groups to develop their own solutions
BENEFITS		
improve public attitude towards science; inform public debate	understand public attitudes to science	fusion of scientific, local and traditional knowledge
improve scientific literacy, counter misinformation, fake news	design communications to fit with how people think and behave	through sustained interaction, communications are atuned to local needs and circumstances
enhance public profile of research - visibility for sponsors / funding agencies	identify target audiences for key messages	democratises decision making
enhanced awareness of key issues	establish credibiity and trust-worthiness	creates new social spaces for deliberation and discourse
	evaluate effectiveness of interventions	
SKILLS		
writing and talking popular science; story-telling / use of visual imagery	understanding basic cognitive science - heuristics, biases, mental models, framing	interpersonal competence; empathy; authenic listening; self-reflection
media literacy; journalistic practice; social media and digital technologies	audience segmentation - focus groups, surveys, questionnaires	participatory mapping; co-design; social learning
media training and presentation skills	social theory - identity, representation and networks	negotiation, facilitation & conciliation
production of creative content	monitoring, evaluation and learning (MEL)	creative art-science practice
KEY INTERACTIONS		
Journalists	Risk management practitioners; planners	Communities and their representatives; teachers / schools
Press teams; media centres	Cognitive and social scientists	Humanities: philosophers,historians
Media producers (graphic designers, film-makers,video games, VR/AR)	Lobbyists, policy advisors; government officials	Artists and creative professionals

Fig. 10. A synthesis of the main characteristics of dissemination, dialogue and participation modes of science communication.

> opportunities to capture baselines are missed. Building effective monitoring and evaluation systems into risk communication initiatives increases the chances of success and informs future investments."
>
> (UNDRR, 2022, p.132)

It would seem that a more robust evidence base is needed to evaluate 'what works' on the ground in disaster risk communications. One approach is to devise high-quality randomised trials and appropriately-analysed cluster randomised trials in the field of disaster risk communication (Bradley et al., 2016). Another is to develop broader quantitative and qualitative measures to gauge whether at-risk individuals and communities have improved their knowledge of resilience-related issues, are more motivated to discuss those issues with people around them, feel more confident about their ability to act and, ultimately, are taking simple actions that could support them to adapt to the shocks and stresses they were experiencing. Key measures might be: Reach (did the interventions reach their target audience?); Engagement (were audiences engaged regularly?); Knowledge: (did audiences know how to counter the impacts of hazards?); Discussion (did audiences discuss the content of the intervention programmes?); Efficacy (did people feel confident that they could act as a result of the programmes?); Action (were the audience taking action or intending to act?) (Whitehead, 2017). In other words, 'success' ought to be determined by the level of active participation rather than on whether the DRR response 'followed the science'.

In advancing disaster risk communications, interventions that connect risk authorities and at-risk communities ought to be viewed as part of a holistic engagement 'process' to deliver strategic goals of risk reduction rather than as a suite of discrete 'products' to inform, educate or persuade. In most multi-faceted DRR projects, this will probably require a continuum of strategies and practices that mix and integrate dissemination, dialogue and participation. For that reason, communication training within DRR projects ought to develop capacity-building initiatives that up-skill risk experts in one-way, two-way and three-way communications.

They key mindsets and skillsets of these three modes of science communication are very different (Fig. 10). One-way communications require the risk expert to become a 'better' communicator, by drawing on media and journalistic practices, enhancing their media literacy, and appreciating the importance of storifying dry technical science through engaging non-technical narratives. Two-way communications require specialists to have a keener sense of the specific audience they are trying to reach, and to draw on empirical experiences in the social and human sciences in devising ways to reach them that shift the focus from conveying scientific 'matters of fact' to conversing around societal 'matters of concern'. Three-way communications draw on community-based participatory education, health and creative art practice and local deliberative governance experiences to strengthen the connection between citizens and risk authorities, manage conflicting interests and ensure equity and inclusivity in risk decision-making.

8. Conclusion

Disaster risk communications can be advanced by DRR practitioners recognising that there is a growing empirically-grounded, evidence based 'science' about what communication interventions are likely to work in different crisis contexts. Understanding the nature of the target audience, specifically the at-risk public, requires a reframing, and even a reimagination, of our collective (technical and lay) knowledge of hazard, vulnerability and risk. Moreover, it is important for technical specialists to appreciate that communication is a process, not a product, of long-term strategic thinking. Communication interventions are not an 'end game' of disaster reduction efforts but rather a 'golden thread' woven through the prevention, preparedness, response, and recovery phases of the disaster 'spiral' (Bosher et al., 2021). Crucially, given the complex multi-faceted and multi-sectoral nature of disasters, 'one way', to 'two way' and 'three way' communication interventions are all likely to be required, and so training and experience in all three modes will be needed for disaster risk specialists. In that context, disaster risk communications offers a coherent continuum of practice that progresses from seeing at-risk communities as a problem to be overcome through education, to cultivating them as resource to be motivated and persuaded, and finally empowering them as a local solution for helping delivering long-term and strategic disaster risk reduction goals. Moving through one-way, two-way and three-way communication modes involves an increasing level, intensity and commitment of engagement between risk authorities and risk publics, but it is the blending of all three modes that will be essential if the holistic, people-centred ambitions of the Sendai Framework for Disaster Risk Reduction are to be fully realised.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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