Science-like knowledge as epistemic infrastructure for climate disaster governance

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Abstract

Purpose – We introduce science-like knowledge to address gaps in predictive climate disaster systems that fail to capture hyper-local impacts. Conceived as a complementary epistemic infrastructure to formal science, it extends beyond anecdotal social knowledge to include structured, real-time insights generated by communities and circulated through social media.

Design/methodology/approach – Drawing on conceptual analysis of citizen observations, digital reporting, and grassroots monitoring, we synthesise developments in disaster research and vernacular sensing to demonstrate the epistemic need for alternative knowledge streams.

Findings – Integrating science-like knowledge improves early-warning precision, situational awareness, and adaptive response. Communities function as epistemic contributors, offering granular data that can verify and contextualise model outputs in data-saturated environments.

Research limitations/implications – Embedding science-like knowledge within disaster risk governance (DRG) promotes cognitive justice, strengthens local participation, and better aligns preparedness with uneven climate volatility. We propose a five-step translational framework for operational integration.

Originality/value – Science-like knowledge is conceptualised as a distinct and structurally coherent category of disaster-relevant information that neither replicates scientific method nor collapses into anecdote. Community-generated digital data and vernacular sensing are reframed as critical epistemic infrastructures, particularly in Global South contexts.

Keywords Climate disaster governance, Science-like knowledge, Vernacular sensing, Grassroots epistemic infrastructure, Anticipatory governance, Social media, Cognitive justice

Paper type Conceptual paper

1. Introduction: compound storms and epistemic blind spots

Across intensifying climate volatility, disaster risk governance (DRG) has become increasingly dependent on predictive infrastructures—hydrological models, global climate simulations, and systems that promise to render uncertainty calculable. Yet the intensification of climate extremes reveals a widening disjuncture between what these systems can represent and what communities experience on the ground.

In 2025, the Asia-Pacific region experienced simultaneous ENSO-linked cyclones, including Cyclone Senyar. These overlapping storms exceeded the spatial and temporal resolution of conventional models, producing widespread flooding, infrastructure damage, and highly localized impacts. Such compound events expose limits that extend beyond technical modelling constraints. The multi-scale complexity involved challenges conventional predictive systems' capacity to represent cascading hazards (Zscheischler *et al.*, 2020). These limits can also be understood as epistemic fractures shaping whose realities are being registered, whose risks are being prioritised, and who remains invisible to the state.

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Current climate disasters thus reveal an epistemic infrastructure gap: predictive models remain indispensable yet structurally incomplete without situated knowledge capable of capturing unfolding conditions in real time. This commentary conceptualises science-like knowledge as an emergent grassroots epistemic infrastructure that mirrors—without claiming equivalence—the coherence of scientific data while arising from non-institutional, situated practices. Integrating predictive systems with vernacular sensing reframes DRG as a problem of socio-epistemic justice and infrastructural design, rather than one of model refinement alone.

Vernacular sensing operates as a boundary method mediating between institutional science—stabilised through validation regimes, coordination infrastructures, and policy authority—and science-like knowledge, an emergent system that borrows scientific forms. Crucially, science-like knowledge is neither simply local knowledge nor failed science. It constitutes a hybrid epistemic formation that adopts scientific techniques, measurements, and classificatory practices while operating beyond institutional regimes of accreditation and authority. Its legitimacy derives from situated utility rather than formal recognition.

For example, during the 2020–2021 floods in Malaysia, residents circulated time-stamped updates, recorded water levels, and shared GPS-tagged locations, generating structured and semi-structured observations that mirrored scientific monitoring practices (such as sensors placed by institutional researchers or meteorological agencies measuring rainfall) while remaining outside institutional validation frameworks. These practices illustrate how vernacular sensing translates lived experience into systematically organised signals, rendering unfolding conditions legible to coordination efforts without relying on formal accreditation.

The paper makes explicit the political and epistemic conditions under which science-like knowledge redistributes—or fails to redistribute—epistemic authority within DRG. Disaster is treated as both process and event: slow accumulations of vulnerability punctuated by crisis moments in which institutional blind spots become visible. Science-like knowledge operates across preparedness, response, and recovery, but its epistemic value becomes most apparent during moments of rupture, when predictive systems reach their limits and translational interfaces determine whether community-generated evidence supplements institutional thresholds or merely aligns with them.

2. Formal forecasting and the limits of disaster risk reduction

2.1 Technical limits of predictive models

Hydrological and climate models remain central to disaster risk reduction, yet their operational utility is constrained by persistent resolution gaps. Recent Northeast Monsoon flood episodes in Malaysia illustrate this challenge. Although heavy rainfall can be anticipated at broader temporal scales, extreme precipitation exhibits substantial spatial and temporal variability across regions, limiting the granularity of actionable forecasting and response guidance (Alzian *et al*., 2025). Rescue teams were forced to shift from pre-emptive evacuation to reactive deployment as waters rose more rapidly and in locations other than those anticipated. Malaysian flood scholarship indicates that while flood dynamics are strongly shaped by seasonal monsoon patterns, flash floods are frequently driven by short-term intense rainfall within small geographical areas, producing rapid, localized impacts that may only become visible once disruption is already underway (Rosmadi *et al*., 2023).

The gap between prediction and coordination highlights a broader problem. Knowing that extreme rainfall will occur does not automatically translate into actionable guidance about who will be affected, how infrastructure will fail, or how populations will respond. Effective disaster governance therefore requires data not only about physical hazards but also about socio-economic vulnerability, behavioral responses, and zones of informational opacity. Such heterogeneous forms of knowledge converge into what can be understood as a science-like knowledge infrastructure: anchored to scientific reasoning yet produced through distributed, non-institutional practices.

Here, ‘science’ is treated as an institutionalised practice whose authority is stabilised through validation regimes, coordination infrastructures, and governance arrangements. Science-like knowledge differs not by what it knows, but by how it is produced, authorised, and mobilised relative to these institutional structures. Gieryn’s concept of boundary work (1983, 1985) shows how scientists actively construct distinctions between legitimate and illegitimate knowledge claims in order to secure credibility and resources. Public understandings of science are consequential, shaping how knowledge circulates and is mobilized beyond institutional contexts.

Power asymmetries play a decisive role in this configuration. Institutions with concentrated resources—technical expertise, policy authority, and infrastructural capacity—possess a decisional reach that far exceeds under-resourced communities. Yet institutional dominance does not eliminate the need for alternative knowledge systems. Rather, crises expose the limits of centralized epistemic authority. Community-built Geiger counters and dosimetry devices following the Fukushima disaster (Polleri, 2019) exemplify how scientific protocols can be redeployed for social purposes without challenging official narratives and standards that define risk. Such practices reproduce elements of scientific measurement while contesting institutional monopoly over interpretation.

These limitations are not unique to Malaysia but reflect structural features of knowledge production. Predictive systems rely on historical data to generate probabilistic futures, whether through global climate simulations or localized impact models. Sparse observational networks across much of the Global South further constrain accuracy, while scaling models for macro-level estimation systematically obscures micro-level anomalies (Lynch, 2008). Increasing computational sophistication cannot fully resolve this mismatch because the problem lies not only in technical capacity but in the sociotechnical conditions of knowledge production.

Understanding science-like knowledge requires situating it within broader genealogies of epistemic formation. Drawing on Foucault’s (1994) reinterpretation of knowledge genealogies, anticipating later theorisation on epistemic infrastructures, science-like knowledge traces discontinuities and contingencies that make particular forms of knowledge possible rather than assuming linear scientific progress. Science-like practices emerge not as imperfect imitations of science but as situated responses to conditions where institutional systems prove insufficient. They reveal how epistemic authority is historically constructed rather than inherently fixed.

Finally, critiques of disaster research highlight how epistemic infrastructures can reproduce ethical and political hierarchies. Institutional priorities and donor frameworks often marginalize local knowledge, rendering affected communities objects of intervention rather than participants in decision-making processes. Funding priorities and technical frameworks channel community knowledge into forms that fit administrative systems, leaving residents treated more as beneficiaries than as partners in shaping decisions. Vaughn (2022) shows that engineers’ archival record-keeping is not neutral: it helps cultivate professional credibility and stabilise an epistemic community, shaping how flood knowledge becomes legible within state-sponsored climate adaptation projects.

Epistemic dominance therefore concentrates where resources and authority converge, limiting possibilities for horizontal power sharing. Science-like knowledge does not claim independence from scientific frameworks; it necessarily references them because those frameworks structure legitimacy and risk. Yet shared epistemic taxonomies do not preclude disruption. They create conditions under which alternative interpretations, priorities, and modes of coordination can emerge, revealing how knowledge infrastructures both constrain and enable crisis response.

2.2 Social and operational gaps

The limits of predictive modelling extend beyond technical issues. Climate-related disasters exhibit the characteristics of what Rittel and Webber (1973) describe as “wicked problems,” where uncertainty cannot be neatly contained within probabilistic forecasts. Disaster governance continues to privilege prediction, yet the gap between model outputs and the requirements of anticipatory governance (Guston, 2014) remains wide. While DRG formally encompasses coordination, infrastructure planning, and multi-actor decision-making, predictive infrastructures remain epistemically dominant in practice, shaping which forms of evidence become actionable and whose knowledge is authorised during crises.

This gap reflects an ontological misalignment. Scientific models function through "indirect representation," constructing simplified worlds that stand in for more complex realities (Godfrey-Smith, 2006). Hydrological models may compute fluid dynamics with precision, yet they abstract away the social variables—informal housing, improvised infrastructure, blocked drains, uneven maintenance—that decisively shape how water behaves during a crisis. A hazard may be correctly forecast, but the resulting disaster emerges through cascading social vulnerabilities that lie outside the scope of formal modelling. This shapes what counts as evidence and what can be mobilised for correction, especially where evidence becomes ambiguous or non-legible. Institutional actors who define evidentiary thresholds and operational criteria therefore shape how disaster is defined and how that definition influences operational policy.

Moreover, evidence operates in at least two registers: physical indicators such as atmospheric data, and social indicators reflecting how behaviours or political-economic conditions amplify disaster impacts. Blind spots in both registers stem from which narratives are privileged and how evidence is operationalised. Recovery has been operationalised through measurable benchmarks of "return to normality," including thresholds for livelihoods restoration and rehousing (Platt *et al*., 2025). Such standardisation enables institutional comparison and decision-making, but may also render forms of social evidence that resist quantification less visible within recovery assessment processes.

For instance, historical cases illustrate how communities fill these blind spots. After the Fukushima disaster, citizens organised independent food-safety monitoring (Sternsdorff-Cisterna, 2015); during Hurricane Sandy, volunteers documented infrastructural failures unnoticed by remote experts (Liboiron and Wachsmuth, 2013). These groups effectively created parallel epistemic infrastructures, generating situated, real-time risk assessments where institutional data was missing or insufficient. Wynne's (1992) work reminds us that such lay expertise is often locally grounded and conceptually robust—not anecdotal, but structurally necessary in the context of institutional limitation. Vaughn (2022) shows that engineering archives do not merely record conditions but shape expertise and how flooding becomes knowable. This suggests that alternative monitoring practices may encounter similar constraints when their observations pass through institutional archival and classificatory systems to become actionable.

These dynamics are visible in ENSO-driven hydrological extremes. They involve the translation of large-scale climatic variability into uneven local disruptions mediated by socio-material water systems. Although ENSO anomalies appear as regional precipitation deficits, their consequences emerge through infrastructure distribution, groundwater dependence, allocation regimes, and household coping capacities. As climatic signals move through these uneven systems, scarcity emerges not as a uniform hydrological condition but as socially differentiated patterns of access, labour, and vulnerability. Hydrological disasters cannot be defined solely by anomalous water conditions but must be understood as emergent disruptions within socially organised processes of water provisioning and governance, consistent with observations that water may function as resource or hazard depending on contextual vulnerability (Weichselgartner, 2001).

Macro-scale climate models reliably predict El Niño conditions months in advance, but they remain blind to the social disasters that follow: localised water shortages, household-level rationing, village wells running dry. Integrated Assessment Models underestimate the moral and distributional dimensions of such impacts, especially for vulnerable populations (Frisch, 2018). The limitations arise not from inadequate computation, but from the abstraction of the social conditions through which hazards become disasters.

Across these cases, communities increasingly build what Bowker and Star (1999) call "boundary infrastructures"—assemblages that translate coarse-resolution forecasts into actionable, situated strategies. Aggregating citizen-generated observations, from soil moisture to tap-water salinity, produces a form of knowledge that operates alongside institutional science rather than outside it. This underpins the emergence of science-like knowledge at the boundary between the wicked realities of contemporary climate disasters and the structural limits of formal expertise. Science-like knowledge, located across preparedness, response, and recovery, can be understood as a strand of postnormal science in which science-based problem solving is broadened to include non-science epistemologies and participatory sense-making in the negotiation of crises (Lee, 2023).

2.3 Incorporation risk and political trajectories of science-like knowledge

Science-like knowledge should not be treated as inherently emancipatory. Its political effects depend on how it is incorporated, by whom, and under what conditions of validation. These trajectories are also shaped by sponsorship and organisational positioning. Community monitoring may be supported by state, corporate, or NGO infrastructures, which can expand technical capacity while simultaneously narrowing the terms on which harms, thresholds, and validity are contested. We therefore distinguish two political trajectories.

Epistemic supplementation occurs when science-like knowledge forces revision of dominant decision frameworks: it exposes blind spots, reframes what counts as harm, and expands the evidentiary field through which preparedness, response, and recovery are coordinated. The legibility of social data becomes a lever for recalibration rather than compliance.

Epistemic alignment occurs when science-like knowledge becomes actionable only by adopting dominant metrics and thresholds. Participation is permitted without redefining authority: data is absorbed into institutional systems while the standards of harm, validity, and intervention remain unchanged. Polleri's (2019) analysis of post-Fukushima citizen monitoring is instructive here: DIY measurement can expand monitoring capacity while leaving state-defined thresholds intact, increasing legibility without redistributing authority.

This distinction clarifies the governance stakes of science-like knowledge: the key question is not whether communities can generate data, but whether institutional interfaces allow community-produced evidence to contest thresholds, redefine priorities, and alter operational decision pathways—rather than merely supplying inputs to pre-existing validation regimes.

3. Science-like knowledge as an epistemic complement

3.1 Origins: epistemic debris and mimicry

As the value of such knowledge is tested through responses to recurring climate extremes, we turn to its epistemic foundations. To theorize science-like knowledge in the context of disaster governance, we begin with the epistemic "debris" produced through traditional classificatory systems.

Drawing on Bowker and Star's (1999) analysis, formal hydrological models operate by sorting complex realities into standardized categories, necessarily discarding whatever cannot be readily quantified as "noise." But the decision over what counts as noise is not power-neutral and depends on how disaster-relevant data are scoped. As shown elsewhere (Lee, 2024), what is considered noise is shaped as much by institutional discourse as by dominant epistemic practices. Noise becomes discarded excess.

We define science-like knowledge as the recuperation of this discarded excess: a form of emergent information that arises from ad hoc, non-institutional practices yet exhibits a systematic coherence akin to formal scientific data. It performs a distinct mode of mimicry, adopting the structural aesthetics of scientific authority—precise measurements, timestamps, geolocations—while remaining outside the conventional lexicon of institutional science. By speaking the language of the state while operating beyond its protocols, this knowledge renders the experience of disaster legible to technical systems, transforming situated observation into a parallel evidentiary record. Adopting the language of the state does not preclude independent agency in defining what standards matter, as demonstrated in documented cases involving rare earth plants in Malaysia and their associated expertise discourse (Lee, 2023).

To clarify its distinctive epistemic form, science-like knowledge can be understood as comprising several key properties that make it an effective complement to formal scientific modelling:

(1) *Distributed and networked*: It emerges from many dispersed observers and sensing practices rather than a single institutional source, forming an informal but coordinated information ecology. Yet even within such distributed emergence, asymmetries of influence and power can arise, especially where actors have unequal access to and relationships with the knowledge produced.

(2) *Situated and real-time*: Observations are generated from within the unfolding disaster, anchored in immediate material conditions rather than historical datasets or abstract projections. Yet the accessibility of such data is itself structured, shaping which phenomena become visible and to whom.

(3) *Structurally coherent:* Although produced through ad hoc practices, it often follows recognisable scientific conventions such as timestamps, measurements, and geolocations, enabling compatibility with institutional systems.

(4) *Iterative, adaptive, and practically validated:* It gains reliability not through controlled experiments but through repeated use, cross-checking within communities, and direct feedback from environmental changes. This supports governance strategies across preparedness, response, and recovery.

(5) *Translational and integrative:* It is designed to be mobilised into action, providing the granular inputs that allow formal models and governance systems to adjust to rapidly shifting realities. However, such translation does not eliminate power asymmetry.

3.2 A queer epistemic form

Science-like knowledge can be understood as a ‘queer’ epistemic form—its power derived precisely from its refusal to conform to disciplinary boundaries or to be confined by them. This knowledge troubles the distinction between objective measurement and subjective experience. By refusing disciplinary containment, science-like knowledge provides a corrective to the rigidity of predictive models, enabling critique of tools that legitimise science while sustaining parallel narratives with their own modes of falsification. Science in theory and science in practice often diverge in their relationship to abstraction and to the messy proofs generated through implementation. While science-like knowledge shares affinities with postnormal science, a queer approach enables the re-prioritisation of epistemic value and the exposure of blind spots created through prior exclusions, including the demarcation of certain signals as noise. This reframes justice in disaster governance as a question of how epistemic boundaries are drawn and enforced.

Building on this, a queer epistemic form can be specified as an intervention into the binaries that stabilise institutional authority over what counts as knowledge. Orthia and de Kauwe (2023) argue that even the most progressive science communication models often retain a science/public binary in which science remains the privileged epistemic identity, while “others” are positioned as recipients, consultees, or conditional collaborators whose credibility is negotiated on terms set by institutional science. Science-like knowledge does not merely add local detail to model output; it troubles the boundary-work through which certain accounts are treated as evidence and others as anecdote, and through which communities must translate lived realities into scientific categories to be heard.

García-Valero's account of queerness as category slippage strengthens this point: categories become "naturalised" through historical stabilisation that leaves residues, exclusions, and indeterminacies outside the frame, even though these exclusions can be decisive for how realities are lived and governed (García-Valero, 2023). A queer epistemic form thus makes visible that disasters are not only manifestations of environmental anomaly, but socially organised productions of disruption—where the politics of credibility, inclusion, and epistemic authority shape what becomes legible as risk and what remains dismissed as noise.

3.3 Symmetry and epistemic parity

To establish the epistemic grounding necessary for integrating these forms of knowledge, we invoke Bloor's (1976) classical "symmetry postulate". This principle requires analysts to maintain methodological neutrality when assessing competing truth claims. Applied to disaster governance, the symmetry postulate compels us to analyse institutional predictions and vernacular reports as analytically symmetrical systems for ordering and acting on risk—one stabilized through computational infrastructures, the other through community-based practices of survival. This symmetrical framing exposes the incompleteness of predictive science when deployed in isolation.

3.4 Ground truth in synthetic data environments

This reframes the debate between inevitabilism and contingentism not as a binary opposition but as a relationship of augmentation (Soler, 2015). The durability and robustness of science-like knowledge demonstrate that institutional modelling is not the sole epistemological route to safety, but rather one contingent pathway among several. By incorporating queer epistemology as a method for convening science-like knowledge, disaster knowledge pathways multiply and can even appear to be less inevitable to singular co-optation.

Contemporary transformations in digital materiality matter to the aforementioned knowledge stakes. As noted in the context of synthetic data regulation, the digital sphere is increasingly saturated with AI-generated artefacts that blur the boundary between simulation and reality. In a disaster setting, this saturation produces a crisis of verification. Here, science-like knowledge operates as a form of "ground truth"—a vernacular sensor capable of validating synthetic simulations against material conditions on the ground. It functions as a defence mechanism, identifying the subset of data that resists synthetic distortion by virtue of its situated provenance.

The growing integration of generative AI into emergency response systems illustrates the relevance of this function. Generative AI has been proposed as a basis for enhancing emergency response decision support by enabling massive heterogeneous data processing, knowledge mining, and strategy optimisation, including scenario-linked response strategies across decision stages (Shan and Li, 2024). Platform-based AI tools have also been discussed as mechanisms for generating situational analyses and response-oriented content within disaster management contexts (Abid and Sulaiman, 2025). These developments expand analytical capacity but also foreground the dependence of AI-generated outputs on upstream data representations. Under such conditions, science-like knowledge provides a materially anchored reference point through which synthesised outputs can be interpreted, corroborated, or challenged.

This reframing carries institutional implications. Formal incorporation of science-like knowledge into disaster governance risks reinforcing existing power asymmetries unless accompanied by interfaces that enable collective and participatory intervention. Absorbing vernacular data into state systems without transforming decision-making architectures risks epistemic extraction rather than collaboration.

The development of standards for science-like data could represent a site of liberatory potential, but only if such standards remain legible, non-bureaucratic, and materially accessible to communities generating the data. Protocols demanding heavy institutional resources or technical credentialing risk reproducing the exclusions they aim to resolve.

Citizen science may function as an intermediary channel for constructing hybrid verification and validation systems. Rather than displacing institutional science, these systems could operate as distributed ground truth infrastructures, enabling iterative calibration between formal models and situated observation. We do not assume that such hybrid arrangements are immune to capture; the history of participatory governance demonstrates that incorporation can neutralize dissent as easily as it can empower it. The design of accountability interfaces is therefore as politically consequential as the knowledge they mediate—an implication consistent with Bloor's symmetry postulate.

3.5 Translational integration and cognitive justice

To operationalise this framework, we draw on Leonelli's (2013) concept of "translational integration." Leonelli argues that effective knowledge mobilisation requires reconciling data from sources both within and outside academic institutions. Its orientation is pragmatic rather than epistemic: the goal is not abstract coherence, but the production of actionable interventions. This aligns with the imperatives of DRG, where the timeliness, relevance, and interoperability of information can determine life-saving outcomes.

Leonelli's example of landowners' photographs serving as critical evidence within institutional scientific workflows illustrates how non-academic data can become integral to formal systems without collapsing into them. In the context of climate disasters, science-like knowledge operates similarly: it supplies granular inputs that enable predictive infrastructures to recalibrate in real time. Science-like knowledge extends its operational reach by furnishing granular, situated data that formal modelling infrastructures cannot independently generate.

This integration, however, is not politically neutral. Translational integration can follow one of two trajectories identified earlier: epistemic supplementation or epistemic alignment. In supplementation, community-generated data reshapes evidentiary thresholds, reframes what counts as harm, and influences operational decision-making. In alignment, science-like knowledge becomes legible only by conforming to pre-existing standards of validation, expanding monitoring capacity without redistributing epistemic authority. The institutional design of interfaces—how data is validated, who authorises it, and how it enters decision pathways—determines which trajectory prevails in practice.

Here, the principle of cognitive justice becomes relevant. As Santos (2014) argues, "there is no global social justice without global cognitive justice." In the context of disaster governance, cognitive justice does not imply the equalisation of all knowledge claims, but the redistribution of evidentiary legitimacy within operational frameworks. Recognising citizen-generated data not as noise but as a potentially authoritative input challenges the structural erasures embedded in what Santos terms the "abyssal line"—the exclusion of non-institutional knowledge from formal regimes of truth.

Through carefully designed translational interfaces, predictive infrastructures can become not only more empirically robust but also more inclusive and adaptive. By populating existing models with granular, previously absent data, science-like knowledge calibrates predictive systems against the lived, uneven, and rapidly shifting realities of the Anthropocene. In this sense, cognitive justice is not an abstract ethical addendum but a governance question: under what conditions can distributed, situated knowledge meaningfully influence institutional thresholds rather than merely supply additional inputs to pre-existing regimes of authority?

4. Illustrative patterns from historical and recent disasters

Historical and contemporary disasters reveal consistent patterns in how communities fill gaps left by formal predictive systems. Each case demonstrates how local actors generate science-like knowledge—distributed, real-time, and structurally coherent insights that complement institutional science.

(1) Fukushima nuclear disaster (2011): Citizens independently monitored food safety, identifying contamination patterns that formal authorities could not detect. This grassroots activity translated observations into actionable knowledge, supplementing formal risk assessments (Sternsdorff-Cisterna, 2015). Vaughn (2022) makes clear how alternative monitoring can be incorporated without altering underlying epistemic hierarchies. These practices expanded monitoring capacity, demonstrating the operational coherence of science-like knowledge. While citizen measurements supplemented official data streams, they did not necessarily redefine the standards by which harm was recognised. Fukushima thus exemplifies epistemic productivity under governance constraints: it increases visibility without automatically redistributing epistemic authority.

(2) Hurricane Sandy (2012): Volunteer groups documented infrastructural failures and flood-prone areas overlooked by distant experts. These observations formed a parallel evidentiary record that informed emergency responses and recovery planning (Liboiron and Wachsmuth, 2013). In this case, supplementation occurred at the level of coordination: community-generated data contributed to adaptive response. Yet the longer-term incorporation of such knowledge into infrastructural planning depended on institutional receptivity. The case demonstrates how science-like knowledge can temporarily reshape priorities without necessarily altering the deeper validation structures of disaster governance.

(3) Tropical Storm Senyar (2025, Asia-Pacific): Forecasts underestimated hydrological impacts; extreme rainfall overwhelmed infrastructure. Community reports and monitoring filled the gap, generating fine-grained, real-time intelligence on waterlogging, blocked roads, and emergent vulnerabilities. This illustrates science-like knowledge as ground truth infrastructure under conditions of predictive shortfall. Whether such contributions reshape infrastructural planning or remain confined to crisis response depends on the extent to which translational interfaces permit community-generated evidence to influence decision thresholds.

(4) Zhengzhou rainstorm (2021, China): Social media posts identified 87.5% of officially reported waterlogged sites, showing how citizen observation rapidly mapped localized risk (Li *et al.*, 2024). Science-like knowledge functioned as a rapid mapping infrastructure, providing granular, real-time intelligence. High correspondence with official data could serve as evidence of empirical robustness. The durability of such contributions depends on whether governance systems institutionalise pathways for integrating distributed reporting into early-warning and infrastructural redesign, rather than treating it as post hoc documentation. The case highlights both scalability potential and the dependency of science-like knowledge on institutional interfaces.

(5) German floods (2021): Crowdsourced reports revealed situational awareness and adaptive strategies missed by formal datasets, enabling timely search-and-rescue operations (Moghadas *et al.*, 2023). These examples demonstrate supplementation in action: science-like knowledge provided critical inputs for immediate intervention. Yet sustainability raises structural questions. Reliance on volunteer labour and informal networks may limit long-term integration unless institutional mechanisms

are established to support, validate, and resource such distributed sensing practices. Institutionalisation can increase durability, but it may also recalibrate what counts as legitimate signal.

5. Implications for disaster prevention and management

Integrating science-like knowledge into DRG opens practical avenues for enhancing preparedness. DRG institutions could establish liaison roles and real-time reporting channels to systematically collect, verify, and incorporate citizen-generated observations. As shown in Zhengzhou's 7·20 rainstorm, integrating fine-grained, situational data from social media with conventional predictive models can support more effective hazard response, enhancing early-warning accuracy and guiding targeted interventions (Li *et al.*, 2024).

Lizarralde *et al.* (2024) describe "artefacts" of disaster risk reduction as community-generated, bottom-up initiatives that translate local observations into actionable insights. These initiatives demonstrate how such knowledge can complement formal predictive models. Such initiatives imply locally embedded actors who mediate between observation and coordination, drawing on contextual familiarity and social trust to circulate risk-relevant knowledge. Participation entails monitoring conditions, communicating emerging risks, and mobilising community networks. Participation remains shaped by resource and recognition constraints.

Emotion shapes how people navigate cultural and political processes and mediates how individuals relate to one another and to the state during and after disasters (Kyriakides *et al.*, 2025). This clarifies the affective space science-like knowledge gives credence to, highlighting how it interacts with and complements institutional governance. Science-like methodologies can account for community experiences and state responses, highlighting dimensions of disaster that formal modelling often abstracts away (see Table 1).

Table 1. Illustrative model gaps and science-like knowledge responses in recent disasters

Disaster case	Predictive/institutional gap	Science-like knowledge response	Epistemic implication
Fukushima nuclear disaster (2011)	Limited institutional capacity to detect dispersed food contamination patterns	Citizen food monitoring and distributed measurement practices	Expanded monitoring, while regulatory exposure thresholds remained institutionally defined (alignment tendency)
Hurricane Sandy (2012)	Incomplete documentation of local infrastructure failures and flood-prone zones	Volunteer mapping and documentation of infrastructure breakdown	Supplemented coordination and response, with uncertain long-term institutional incorporation
Tropical Storm Senyar (2025)	Underestimation of fine-scale hydrological impacts and infrastructure overload	Community reporting of waterlogging, access disruption, and emergent vulnerabilities	Functioned as ground truth intelligence during response; influence on planning dependent on translational interfaces
Zhengzhou rainstorm (2021)	Limited real-time mapping of localized waterlogging sites	Social media-based citizen reporting and rapid situational mapping	Demonstrated scalability and empirical robustness; durability contingent on institutional integration pathways
German floods (2021)	Delayed situational awareness within formal datasets	Crowdsourced reporting supporting search-and-rescue coordination	Enabled immediate intervention but raised sustainability and institutionalisation challenges

Source(s): Authors' own work

Science-like knowledge can be operationalised as a framework for translating disaster data between disaster management and climate change management. Alburo-Canete *et al*. (2025) highlights the importance of critical research methodologies that focus on "alternative forms of disaster knowledge", critically examine power imbalances, and apply creative and reflexive methods to engage meaningfully with communities most affected. Using these principles, science-like knowledge can supplement disaster management by informing institutional forecasts and encouraging collaborative, community-focused approaches. Science-like knowledge does not encompass the full domain of disaster risk governance but operates as an epistemic layer within it. It enhances situational awareness by translating lived experience into institutionally legible signals and expanding the evidentiary field. It does not replace institutional functions such as planning, resource allocation, or regulatory intervention, nor does its production automatically translate into decision authority. It shapes the knowledge environment within which governance occurs, supplementing predictive systems while remaining contingent on institutional interfaces for uptake.

The translational framework can be operationalized in five steps:

(1) Knowledge Mapping: Institutional and community-generated data are mapped to identify knowledge sources and gaps, recognising situated observations alongside conventional models.

(2) Data Processing: Data are collected and processed through transparent protocols that stabilise dispersed observations while preserving contextual specificity.

(3) Equity Safeguards: Validation and integration procedures are designed to prevent participatory exclusion and epistemic extraction, ensuring accountability in how community data are authorised and used.

(4) Knowledge Integration: Translated knowledge is incorporated into institutional decision pathways in ways that allow thresholds, priorities, and planning assumptions to be revised.

(5) Continuous Learning: Ongoing monitoring and evaluation embed feedback loops that recalibrate both operational preparedness and institutional validation criteria over time.

These translational activities contribute to disaster risk reduction by reshaping the knowledge conditions that make that intervention possible. Knowledge mapping expands heterogeneous risk signals, while data processing stabilises dispersed observations into forms that support coordination across disaster phases. Equity-oriented practices prevent participatory exclusion, integration enables situated observations to inform planning and modelling, and continuous learning embeds adaptive recalibration into governance systems. These processes operate upstream of material response, shaping how risks are recognised, prioritised, and acted upon across preparedness, response, and recovery.

Integrating science-like knowledge requires attention to protocols, validation, and governance design. Ethical and methodological guardrails are necessary to manage biases, maintain data quality, and prevent epistemic capture. When appropriately integrated, these mechanisms create a robust feedback loop: predictive models inform community action, while community observations refine institutional forecasts, expanding the epistemic and operational horizons of DRG.

6. Conclusion: repositioning public epistemic labour in disaster risk reduction

Science-like knowledge is not a peripheral add-on to disaster modelling; it represents an essential epistemic layer for anticipatory governance under conditions of escalating uncertainty. By complementing institutional models, it captures hyper-local, real-time conditions that formal predictions often cannot register. It recalibrates institutional foresight, enabling decision-making that is more responsive, adaptive, and socially inclusive.

Tropical Storm Senyar is an apt illustration of this necessity. While models predicted a weakening wind field, extreme rainfall overwhelmed water infrastructure, exposing the limitations of predictive accuracy at scale. Community observations, citizen-generated data, and grassroots monitoring—through on-the-ground reporting—filled this gap, providing actionable intelligence that supported real-time interventions. Integrating such science-like knowledge into disaster risk reduction frameworks strengthens anticipatory capacity and aligns governance with the complex, uneven realities of compound climate events. Future multi-hazard crises will increasingly demand that DRG systems recognise, validate, and incorporate public epistemic labour as a structured complement to institutionally legible knowledge categories.

Acknowledging and integrating science-like knowledge transforms communities from passive subjects of prediction into active epistemic partners, locating disaster governance within epistemic infrastructures under escalating uncertainty. The convergence of institutional modelling and science-like knowledge marks a critical step toward a more adaptive, equitable, and cognitively just approach to survival in a world where the frequency and intensity of disasters will continue to exceed the limits of prediction.

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