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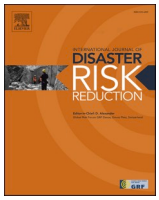

Mapping boundary interactions across earthquake science and humanitarian-development communities for disaster risk reduction

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ABSTRACT

Building on social learning theory and employing a case-study approach this paper set out to explore the degree and nature of boundary interactions taking place between earthquake scientists and humanitarian-development non-governmental organisations as two stakeholders in disaster risk reduction. Framing boundary work(BW) as an inclusive process of active participation between social worlds, it draws on qualitative interview data to develop and analytically employ a boundary working typology to map the social mobility of earthquake scientists and NGO practitioners across Community of Practice boundaries. While the analysis identifies a number of individuals to be socially interacting in modes of boundary learning fitting of the typology, it uncovers additional boundary processes including varying efforts to manage community boundaries. It finds one-off encounters marked by transfers of explicit information to present the dominant form of engagement and flags a number of challenges associated with maintaining more socially-rich boundary learning interactions. Personal boundary relationships prove of critical importance and the potential for gatekeeping individuals and institutions to act in a supportive capacity is highlighted. Aiming to bring a richer level of analysis to the complexity of boundary processes taking place the paper presents a transferable tool with the utility to aid self-reflection in attempting to navigate the boundary landscape while allowing funders to gain a greater appreciation of the many forms BW can take in order to better support it.

1. Introduction

Spanning environmental and social realms alike, the complex and multifactorial nature of disasters requires multi-stakeholder collaboration for the effective reduction of risk. As such, Disaster Risk Reduction (DRR) sees increasing calls for multidirectional action from both top-down and bottom-up interventions and shared learning across all scales and sectors [1,2]. Adopting a social learning approach, and placing its analysis within a Community of Practice (CoP) framework, this paper moves beyond a growing focus on knowledge exchange (KE) to put forward an understanding of boundary work (BW) as an inclusive social process of interaction across community boundaries. Focusing specifically on earthquake science and humanitarian-development Non-Governmental Organisations (NGOs) as stakeholders in DRR, this paper develops a boundary working typology to illuminate the nature of social interactions taking place between them. The need to achieve an insight into the collaboration efforts existing between these groups is reinforced through the Sendai Framework for Disaster Risk Reduction 2015–2030, which places unprecedented emphasis on the importance of research while calling for greater insight into science's existing networks in DRR [1]. Acknowledging a lack of guidance on how to actually 'do' boundary work in practice [3,4] and paying heed to Reed et al.'s [5]; p.338) concern that efforts tend to be ad-hoc with "little theoretical, methodological, or empirical grounding", the paper answers scholarly calls for theoretical frameworks providing greater understanding of science-humanitarian collaboration in DRR [6], increased insight into the positionality and movement of individuals engaging in BW [7], and the development of a framework that provides a baseline for future guidance on science-policy-practice processes [8].

Employing a case-study approach and drawing on qualitative interview data the analysis utilises and expands upon the BW typology as an analytical tool. Despite efforts by earthquake scientists and NGO practitioners to socially interact in ways fitting of the typology, it finds one-off encounters to be the dominant form of cross-CoP engagement due to challenges associated with maintaining higher levels of participation in boundary learning. While investing in personal cross-CoP relations aided in overcoming some of these difficulties on an individual basis, the analysis uncovered wider efforts to manage CoP boundaries and

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highlighted the potential for those with gatekeeping capabilities to provide support for boundary working interactions.

2. Towards a social process of boundary interactions

Recognition of the need to bridge an apparent gap between research and decision-making has been well documented, both in the context of disaster risk and more generally across knowledge-action systems [3,9]. Depicted by McNie [8] as an artificial separation that creates unnecessary barriers to science-society connections; there is broad agreement amongst scholars that heightened engagement across these socially constructed boundaries would enable greater relevance of science while increasing the value placed on other knowledge forms [3,8,10].

Processes of collaborative learning and co-engagement remain particularly under-analysed between science and NGOs [11]. While Perz et al. [12] highlight a need for greater linkages between environmental science and NGOs, Shannon et al. [6], call for further research into the social dimensions surrounding science-humanitarian collaboration in DRR. NGOs play a crucial role in reducing risk where unequivocal levels of poverty and inequality lead to higher vulnerability and disaster impacts [13]. Critical actors of the humanitarian system their presence at grassroots level and utilisation of participatory approaches is perceived to enable a more 'people centred' type of DRR [14]. Whilst they embody a wealth of experience and social knowledge themselves, they are also in a key position to bring together various forms of knowledge such as indigenous and scientific. Despite this, an analysis of humanitarian action carried out by ALNAP found multi-sector collaboration for risk reduction to be rare within NGOs, with DRR initiatives tending to be small scale and single sector [15].

Knowledge sharing for DRR has traditionally been conceptualised and implemented in accordance with what has become known as the 'deficit model' approach; so named due to its assumption that society is deficient in its understanding of hazards, their associated risks and the means of overcoming them [16]. Marked by the increasing supply and unidirectional flow of often irrelevant and inaccessible scientific information to decision-makers and those considered 'at risk', it views knowledge as an explicit object that can be easily transferred. The ever growing focus on KE marks a move away from linear models of information transfer towards the bidirectional flow of knowledge between those typically thought of as producers and users of knowledge [5,17]. Recognising that the value placed on science is often highly contingent on socio-cultural contexts, KE is advocated as a means of gaining greater appreciation of the needs, values and knowledge of so-called user communities, often with the aim of producing more useful scientific outputs [5,17]. One could argue; however, that the very term implies a maintained focus on the movement of explicit knowledge (regardless of the direction) rather than the need to enhance co-learning and trusted engagement between social groups. This is in line with Munro's [18] concern that KE still views knowledge as something which can be easily codified and shared. In contrast, social learning theory places a focus on collaboration and interaction as the basis of learning and has been increasingly advocated as key to understanding and enhancing learning where complex problems require the engagement of multiple stakeholders for DRR [19,20].

While Fazey et al. [17]; p.205) perceive KE to be made up of "a range of concepts" to include social learning; it is instead possible to interpret KE as one activity embedded within a wider process of social learning. For instance, a social learning approach conceives of learning as a situated process of participation within a given social practice; as opposed to the acquisition of an objective knowledge product [21]. In turn, knowledge exchange can only be seen to move beyond a simple two-way transference of explicit information once it is utilised and grounded within social interaction between groups. Outside of such an approach KE runs the risk of falling captive to McNie's [8]; p.22) criticisms of more linear models of communication by similarly overlooking 'important interactions across scales'. Social learning theory therefore presents an opportunity to begin analysing cross-community engagements as central to collaborative learning.

In particular Wenger's [22] conceptualisation of social learning systems and Communities of Practice (CoPs) provides a framework from which to understand the presence and significance of the boundaries surrounding social worlds like science and decision-making. For Wenger, CoPs are considered bounded social groups identifiable where individuals are united around the three components of joint enterprise, mutuality and shared repertoire. Portraying boundaries as an inevitable outcome of all CoPs he explains how the fostering of strong community identities will in turn lead to the formation of boundaries around their practice. While recognising the potential for boundaries to act as barriers to cross-CoP engagement, he primarily advocates them as critical spaces for innovative learning that should be understood and fostered. In keeping with Cash et al.'s [3] reflection of the permeable nature of boundaries, one of Wenger's [22]; p.232–238) most notable observations lies in his conceptualisation of boundary processes which he presents as having the ability to create bridges between worlds. Despite highlighting their importance, Wenger has been criticised for neglecting to build on the idea of boundary processes for use in empirical analyses [23].

While Wenger [22] puts forward a number of different types of bridging, the role of 'people who act as brokers' has received the most attention as a means of enhancing communication across the knowledge-action divide for DRR [24,38]. This reflects a general growth in literature advocating the role of knowledge brokers as individuals who commit to creating connections between research and decision-making, often on a professional basis [25]. Despite recognising the potential value of such intermediaries, it is possible to see how Wenger's [22]; p.235) definition of a broker as someone involved in 'import-export' fits directly into a linear model of knowledge transfer. Furthermore, Turnhout et al. [26]; p.359) raise concerns that the use of dedicated titles such as knowledge broker could harmfully present an individual as the 'exclusive owner of knowledge' and cross-CoP engagement as 'someone else's job'. This paper seeks to move beyond the focus on brokerage as a role for 'certain individuals' by bringing its attention to Wenger's [22]; p.235-6) least explored bridging concept of 'boundary interactions'.

Addressing a gap in literature surrounding the attempts of CoP members themselves to interact across boundary space, it adopts the more holistic concept of boundary working (BW); defining it as a social process of participation and interaction across social worlds within which brokerage and KE may be employed. Acknowledging that different types of boundaries may require diverse forms of BW depending on the social context the research draws on Owens et al.'s [27]; p.640) interpretation of boundary work as a process of 'acting in and around [a boundary] while recognising it is not rigidly defined'. It therefore does not fixate on the movement of knowledge but instead explores the potential for people themselves to engage in boundary processes through their physical movement across social worlds. Concerned with the overall nature of human participation and social mobility at boundary interfaces it aims to reflect an inclusive process that is not only open to designated intermediaries, but to earthquake scientists and NGO practitioners alike. Recognising the need for science to play a diversity of roles in society, Pielke [28] marks an attempt to classify the role of scientists within decision-making processes; however, his work is concerned with the extent to which researchers wish to influence decision outcomes rather than the attempts of both science and practitioner communities to socially navigate across boundary space. Whilst his focus on the use of explicit knowledge places his typology within KT perspectives the following analysis makes effort to consider their relation to social interaction where relevant.

3. Methodology

Employing a case-study approach this research draws on primary

data gathered from 64 semi-structured interviews held with members of both the earthquake science community and humanitarian-development NGOs in the UK and Ireland. The earthquake science community referred to within the case-study is made up of 29 earthquake scientists working as professors, lecturers, post-doctoral and PhD researchers within UK universities known for quality research into seismic hazards, as well as science institutions including the British Geological Survey (BGS), Natural Environment Research Council (NERC), and The Centre for Observation and Modelling of Earthquakes, Volcanoes and Tectonics (COMET). Snowball sampling resulted in an additional key informant interview being conducted with a local earth scientist based in Haiti.

The humanitarian-development community comprised 32 staff from international NGOs with their headquarters in the UK and Ireland, including Concern Worldwide, Christian Aid and CAFOD. Participants held a variety of roles within their organisation deemed relevant to the study; including those whose work focused on geographical areas of earthquake risk, DRR advisors, and the heads of both an emergency unit and advocacy and learning department. The snowballing technique led to the identification of two further key informant interviewees who were found to be acting in an intermediary capacity across the earthquake science-NGO boundary interface. This case-centric focus allowed one to draw conceptual boundaries around a specific set of group dynamics to aid in capturing an understanding of the interactions taking place within a particular social space. This research therefore does not claim to be representative of wider earthquake science-NGO boundary working, nor characteristic of science-NGO relations across other disciplines, hazard types or geographical locations; instead it aims to highlight the nature of engagements taking place in an individual case at a particular point in time.

Adopting a social learning approach the methodology builds on the interpretation of learning as a process of participation to frame boundary working as the attempt to engage in learning across social worlds. Grounded in social and situated learning theory, it in turn recognises one's experience of boundary learning to be determined by their movement and position in relation to the core practice and boundaries of communities. Focusing on the 'process of interactions' as recommended by McNie [8]; p.18), the analysis addressed scholarly concerns over a lack of understanding surrounding modes of BW and the invisibility surrounding the positionality and movement pathways of those undertaking it [7,25,29]. In doing so it recognised the analytical potential of previously overlooked elements of Wenger's [22] work; particularly his identification and classification of the following four means of brokering;

1. **Boundary Spanners** – taking care of one specific boundary over time,
2. **Roamers** – going from place to place, creating connections, moving knowledge,
3. **Outposts** – bringing back news from the forefront, exploring new territories,
4. **Pairs** – often brokering is done through a personal relationship between two people from different communities and it is really the relationship that acts as a brokering device.

[22]; p.235-6).

Despite Wenger [22] placing them within the brokerage umbrella his description of each type is more reflective of wider processes of social participation and the movement of people across boundaries. In fact, aside from briefly labelling the roles Wenger [22] leaves much of the interpretation up to the reader, failing to provide further analytical insight or detail on how they might play out in practice. Building on this unmet potential the analysis reframes Wenger's concepts within a typology of boundary working interactions. As depicted in Fig. 1 below, the typology was placed within a Community of Practice framework to aid a visualisation of the movement and positionality of each mode of boundary interaction in relation to the earthquake science and humanitarian NGO worlds.

The typology expanded upon the limited descriptions put forward by Wenger, relabelling each concept to reflect a sense of movement rather than a definitive role. For instance, this paper argues that Wenger's

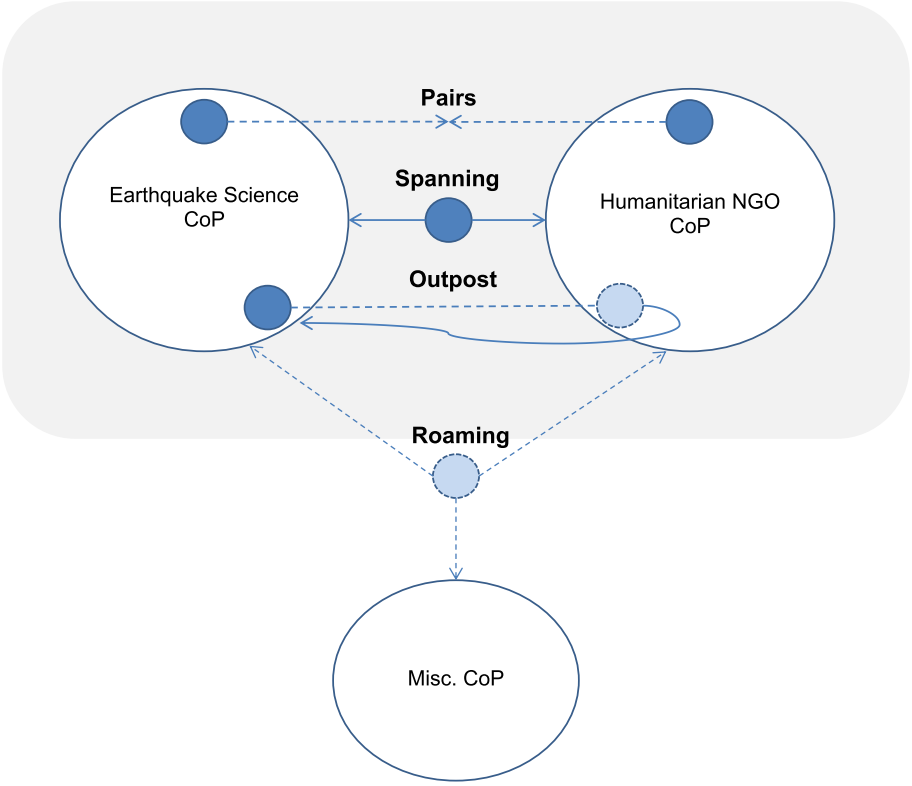

Fig. 1. Model mapping the typology of BW interactions within a Community of Practice framework used to guide the analysis. Large circles represent the relevant CoPs with a third miscellaneous CoP included to aid illustration of 'roaming'. Smaller circles illustrate the interpreted position of those engaging in each mode of boundary participation with the arrows depicting their relative movement within the boundary space. The solid lines represent a level of permanence associated with the interaction, while dashed lines present temporality.

summary of the 'boundary spanner' implies a stagnant position at the periphery of one CoP (rather than one of spanning) where cross-community engagement is only undertaken if essential to that CoP's long-term functioning. In contrast, Fig. 1 depicts spanning not as an activity that takes place at the boundary of one community but as the constant motion between a specific set of CoP boundaries, while roaming is interpreted as the process of moving freely between multiple CoPs. While the model portrays roaming as taking place between three communities it may play out across an unlimited number of CoPs. The typology puts forward an understanding of outpost interactions as the effort made by an individual, or group to temporarily leave their community to participate in the practice of another CoP; such as a secondment or extended placement. The goal is to return to their original CoP with a deeper understanding of another social world and a capacity to impart a new appreciation for a previously unknown domain. In keeping with Wenger's original description, 'pairs' is portrayed as being based on the 'personal relationship' of two participants from separate CoPs. Here boundary learning is likely to manifest informally and at an individual level rather than on an organisational scale.

The analysis employs the typology as an analytical tool and portrays BW as a process open to all by placing its primary focus on the attempts being made by NGO practitioners and earthquake scientists to engage in boundary learning.

4. Boundary working interactions at the earthquake science – NGO interface

There was a general impression amongst interview participants that the *"the humanitarian world and the academic world (were) still very much divided"* in the context of earthquake risk. Despite this, the analysis found increasing attempts at cross-community engagement with the majority of respondents recounting some form of interaction, along with a growing awareness within both communities of the need to work together in delivering DRR solutions. As such, the following section builds on the boundary working typology presented in Fig. 1, while employing it as an analytical tool to shed light on the varying means in which people are attempting to interact across the boundaries of earthquake science and humanitarian NGOs. It draws on empirical data which is italicised throughout.

4.1. Boundary spanning

Of the 64 participants interviewed, 4 were found to be making specific attempts to engage across the earthquake science and NGO worlds through some form of iterative, sustained movement characteristic of boundary spanning (BS). All of these individuals came from the earthquake science community: two Professors, one PhD student and a seismologist temporarily employed as a NERC Knowledge Exchange Fellow. Although this may appear in keeping with the assumption highlighted by Bednarek [10] that those identified as spanners are often scientists working alongside their research role, in reality participants faced great challenges balancing these tasks. It was evident that the time and effort needed to engage in effective BS decreased one's capacity to invest time purely in research often making it necessary to prioritise one activity. This highlighted the potential for varying interpretations of Wenger's [22] concept of 'over time'. As such, the analysis found the individual's interactions to fall within one of two categories; a) those who engaged in spanning intermittently or on a short-term, temporary basis before returning to a long-term goal of research, and b) those for which BS was beginning to form their primary identity. Individuals following this second path were embracing longer-term engagements in BS by making a conscious choice to focus less on conducting pure science in favour of delivering applied research or moving towards roles considered more policy/practice facing.

The two individuals fitting within the first category reported interacting with NGOs sporadically over a period of months/years often as part of short-term funded projects. For example, although the KE fellow described their work as being focused on *"knowledge exchange related activities about increasing the impact of science and research in risk reduction"*, it was suggested that this was a new working focus that would not continue beyond the duration of their funded fellowship, after which they would return to seismology. Similarly, while one Professor made periodic efforts to engage in co-production projects with NGOs he was keen to emphasise that he was a scientist whose focus remained firmly on producing high quality research rather than enabling cross-boundary processes. In contrast, the two participants falling into the second category expressed an ultimate goal of breaking down the barriers between earth science and NGOs and were more reflective of Bednarek's [10]; p.1175) interpretation of boundary spanners as individuals who take on a full-time commitment to literally 'span the boundaries'. In addition to personally interacting across the earth science and humanitarian worlds through workshops and interdisciplinary projects, these individuals were found to take on an advocacy role by lobbying government, funders and scientists on the importance of increasing science-policy-practice relations, as well as setting up organisations, collectives and conferences that brought together members of both communities. Such organisations in turn provided an element of institutional support that allowed them to sustainably maintain their BS engagement. Examples found at this interface included Geologists for Global Development' (GfGD) and the UK Collaborative on Development Research which plays host to the 'Disaster Research Group'.

Bednarek [10] portrays boundary spanners as striving to fulfil Pielke's [28] definition of an honest broker who does not advocate for a particular research finding or decision outcome but aims to provide increased clarity and choice. While Pielke [28] would argue that the individuals identified above could not be viewed as honest brokers given their role as producers of knowledge; this research found all four to be striving towards something more than the basic transfer of information. Interviews uncovered a genuine desire to not only increase the usefulness of their research, but to understand how science might fit alongside other forms of knowledge for risk reduction. As such, they displayed a clear intention to build trust and mutual learning by interacting across the science-NGO interface, with the aim of providing a potential toolkit of knowledge and social connections that could be drawn on when needed. Interestingly, Bednarek [10] does not shy away from identifying spanners as being involved in knowledge creation; however, while he classifies BS as a distinct practice different from science communication and advocacy, this analysis recognises it not as a delimited action but as a form of social participation through which one may draw on a range of methods conducive to collaborative learning.

4.2. Roaming

Boundary roaming by its very nature expands the focus of analysis beyond the earthquake science – NGO interface. This made it necessary to confine the parameters by which social interaction was considered a true example of roaming in keeping with the characterisation put forward by Wenger [22]. For instance, while scientists and NGO practitioners may occasionally engage with multiple social worlds through interdisciplinary or cross-sectorial projects and workshops, these interactions were not identified as boundary roaming as individuals could not be described as physically moving 'from place to place' on a continuous basis. Instead, the analysis focused on instances where boundary roaming was identifiable as the continued movement between three or more CoPs.

Out of the 64 participants interviewed 5 individuals were found to be participating across CoPs in a manner reflective of roaming. Within this, it was possible to identify two distinct categories of roaming; those engaging as a requisite to fulfilling a wider role within their CoP, and those whose primary purpose was to create connections as in a full-time intermediary role. Three individuals fell within the first group, all of which held the title of DRR adviser within their respective NGO. In order

to effectively provide preparedness and mitigation programmes to vulnerable populations they frequently collated and moved knowledge through their interaction across numerous interfaces including between NGOs, science and local/indigenous communities, as well as internally bridging Headquarters and local programmes, and overcoming the "institutional divide" between humanitarian and development departments. Interestingly, this led some NGOs practitioners to claim that they did not need to engage with science on a personal level as the DRR advisers would be doing it.

While DRR advisors were engaged in the physical act of roaming; the purposeful movement of the two remaining individuals was more fitting of a stand-alone roamer role or 'boundary agent' [30]; p.9), whereby they had no particular boundary loyalties but instead moved freely between multiple CoPs with the aim of creating connections and facilitating shared learning between those with humanitarian responsibilities. One individual described their interest as lying not in bringing a specific set of communities together but in seeking to understand how collaboration as a general process could be enhanced;

> *"I am working with corporates, with the military and with scientists … for us it doesn't really matter what you are talking about, it's how you have the conversation"*.

Holding the titles of 'science and policy officer' and 'KE fellow' these individuals lay outside of earth science and NGO CoPs and were instead embedded within boundary organisations which supported their capacity to engage in boundary encounters on a full-time, professional basis. Of all participants they were the most reflective of Pielke's [28] honest broker and Bednarek's [10] interpretation of a boundary spanner as someone who does not push for a particular agenda; however, the activities they carried out extended beyond the basic brokerage of information. Adept at recognising the potential for and initiating new collaborative relations between diverse communities their movement between worlds not only aided the translation and transfer of knowledge but the deeper transformation of stakeholder priorities and perceived challenges to co-learning. While this process of building trust and mutual understanding between CoPs often resulted in the development of joint project proposals, there were concerns that relations between groups would discontinue beyond the intermediary's involvement and the provision of financial support. Despite members from both CoPs advocating the need for intermediaries, they reported job instability associated with the challenge of demonstrating the value of the roamer role explaining that they were less likely to be directly involved in the new co-learning processes and subsequent measurable outputs or impact arising from collaborations.

4.3. Outposts

No examples of outpost boundary working were identifiable among the 64 individuals interviewed; however, there was evidence of wider outpost-type interaction taking place across the earth science-NGO interface. This took the form of earth science postgraduate students engaging in short placements within NGOs facilitated by the boundary spanning organisation GfGD. Placements involved *"shadowing the (NGO employee), going to meetings with them (and) just trying to understand what it is that happens in the development community"* to inform students of *"the skills they need to get into the sector"*. The hosting of earth science students presented a fairly new concept for NGOs who typically supported placements from social science and humanities disciplines. Despite the humanitarian CoP's openness to receiving outposts there was no evidence of NGO practitioners spending time in the earthquake science CoP. As such, there were no established members of either CoP dedicating an extended period of their time to interacting within and learning about the practices of the other community with the intention of sharing this insight with their peers to enhance cross-community relations. Although interested in 'exploring new territories' [22]; p.235) student engagement could be seen as that of a novice attaining personal development and exploring career opportunities.

Given that the only movement typical of this type of boundary work was found at the entry level of the earth science CoP the outpost role could not be strongly identified within this case-study. Beyond this; however, it was possible to identify broader examples of outpost-type initiatives to aid in demonstrating the function and value of such boundary movements. For instance, US programmes such as the AGU Congressional Science Fellowship, and the AAAS Science and Technology Policy Fellowships afford scientists the opportunity to work within government policymaking for one year, while The Roger Revelle Fellowship also encourages employment within the non-governmental sector. Interestingly, only 20–25% of individuals have been found to return to their original research positions on completion of the AAAS fellowship, suggesting that only a minority can be truly classed as outposts 'bringing back news from the forefront' [31]. In the UK, NERC's Policy Placement Fellowship Scheme encourages bidirectional mobility where policymakers can take up placements within research centres, in addition to environmental researchers working alongside policymakers in a range of institutions [32]. With each of the initiatives above placing an explicit focus on policy, this paper questions whether a broader gap remains for outpost placements at the level of NGO practice and programming.

Secondments such as those characterised by outpost boundary interactions allow individuals to foster much deeper appreciations of the collective learning processes and knowledge epistemologies of other CoPs than that gained through engagement in workshops or collaborative projects. Similarly, by becoming fully immersed in another social world they not only gain a unique insight into the complexities associated with sharing learning across diverse CoPs, but they also introduce aspects of their home community into the host CoP. The potential value of such placements had become clear to those working in boundary spanning capacities, with one individual emphasising that *"for a longer lasting relationship … you need people who can sit for a year, take a sabbatical from one job and go somewhere else"*. Despite the promise of enhanced mutual understanding between diverse CoPs, interviewees shared fears concerning the impact of such sustained engagements on their competence and status within their own community. This echoed Wenger [22]; p.237) observations that it may prove challenging for individuals to bring their new learning home, therefore raising questions as to whether outpost-type boundary working places too much responsibility on one individual to build expertise interacting across CoPs.

4.4. Pairs

The case-study uncovered two sets of pairings consisting of one member from each CoP investing in personal relationships for the purposes of sharing knowledge and learning. While one pair took the form of a Professor of earthquake science and the Head of an INGO emergency unit based at UK/Ireland Headquarter level, the other comprised an NGO DRR advisor and earth scientist based in a local area of earthquake risk.

The first example was found to provide the only longstanding link to earthquake science within this particular organisation which proved of critical importance especially during the aftermath of earthquake events when the NGO needed quick, trustworthy information and advice;

> *"The only other link is with John … dating back to the tsunami 2004. Where it was really useful was in Haiti a short time after the earthquake, sitting there able to call John after saying this is what we're experiencing and being able to have that level of contact"*.

This echoes Pelling and High's [33] observation that informal relationships are powerful vehicles for learning which can eradicate the problems associated with bringing different actors together in the crux of disaster response.

The key to the effectiveness of pair relations was found to lie in the friendships and companion-based trust that developed organically and informally overtime. In this way they could be considered high in legitimacy which McNie [8]; p.4 & p.20) interprets as the level of social capital built on mutual trust and respect, and the factor most often found to be lacking in efforts to create and share useful information. These relations were; however, originally born out of competence-based trust, with credibility presenting a critical prerequisite to initiating connections.

The unique advantage of 'pairs' is that it allows one to socially interact with members of other CoPs whilst staying firmly positioned within their own community, in turn posing less of a threat to one's internal reputation than other types of boundary work. Not only did this act as a safety net but maintaining one's CoP status also proved essential to providing long-term assurance that individuals would remain a credible source of information. The possibility of retaining a balance between internal competence and boundary credibility may allow for a more sustainable form of boundary interaction at an individual level; however, concerns were raised with regard to a wider over-reliance on such pair relations. For instance, while the first set of pairs provided the sole link to earthquake science at a INGO headquarter level, local contact with earth science was found to be similarly dependent on the *"personal network"* of the individual DRR advisor in the second pair relation. This highlighted a negative aspect of pair-style BW as both practitioners questioned how their eventual departure may impact the organisation's capacity to carry-out informed DRR. The first pair relationship demonstrated how connections made at a personal level are not bound to organisations, whereby the scientist's move to a new research centre caused his former institution to lose this NGO contact. This echoes the findings of Cahill [34]; p.166) who found 'strong personal connections to be as important, if not more' important than organisational ones in responding to the 2005 Pakistan earthquake.

The analysis also highlighted the underlying importance of personal relationships across other forms of BW. For instance, the boundary interactions of all five individuals previously classified as roaming were found to be largely reliant on an ability to build and maintain key personal relations across social worlds, with DRR advisers proclaiming the benefits of being able to call on a scientist *"as a friend"*. Where such relationships existed they also acted as access points to additional members of the scientific and humanitarian/development community when needed. For this reason it proved difficult to delineate the true number of individuals engaged in pair-style boundary working.

4.5. Expanding the typology

The four boundary working types put forward by Wenger [22] provided a useful starting point from which to explore the nature of boundary interactions taking place between earthquake science and NGOs. A total of 12 individuals could be identified as engaging across the interface in a manner fitting of the typology, with some found to be taking more than one approach, such as engaging in both roaming and pair relations. Rather than concluding that the remaining 52 interview participants were not engaged in boundary processes, the analysis uncovered additional forms of boundary interaction detailed below.

4.5.1. Gatekeeping

While the four types above are framed by Wenger [22]; p.234-5) as a means of bridging social worlds, this analysis uncovered a need to recognise efforts to uphold CoP boundaries as important boundary processes in their own right. As such, it puts forward the 'gatekeeper', a term adopted by Star and Griesemer [35]; p.338) who refer to those in the role as 'obligatory points of passage' whose purpose is the creation or maintenance of scientific authority. This paper builds on their interpretation to present the gatekeeper not as solely interested in science, but rather in managing the boundary of whichever community they belong to. As such, they may act as advocates for social closure, primarily concerned with how boundary interactions may impact upon the identity and practice of their community.

Gatekeeping was found to be evident in two ways; 1) as an underlying sentiment held by CoP members, and 2) as individuals/institutions with the power to act in a gatekeeping capacity.

The gatekeeper sentiment was most apparent in the earthquake science CoP, where it was possible to identify 12 individuals with a particularly strong desire to limit scientific engagement with NGOs, with one researcher emphasising *"we're the experts, or the scientific community are the experts … it can't suddenly shift where the direction of research is being set by someone else"*. While this may present as an attempt to maintain authority, their attitude was driven by a concern for protecting the credibility of science underpinned by a fear that it would be *"a mistake to let research be driven by discussions"* with NGOs. There was a belief that collaborating with NGOs would cause research to *"become too prescriptive"* whereby scientists "*might start to miss those opportunities to make the next big scientific breakthrough"*. A number of interviewees described a similar fear often held by NGO practitioners that engaging with scientists would harm either their personal credibility or that of their organisation by uncovering pitfalls in humanitarian policy, knowledge or practice. While only three NGO representatives displayed a particularly hostile attitude towards science, there was a widespread view that NGOs needed to maintain a focus on beneficiaries rather than high-end research. While Wenger [22] himself alludes to the possibility that boundary interactions may threaten the competence of CoPs, this analysis echoes the suggestions made by Cash et al. [3] and Michaels [36] that science and policy exhibit equal desires to maintain their boundaries.

Evidence of those working in a gatekeeper capacity was perfectly epitomized in individuals and institutions with the influence to dissolve or erect barriers to cross-CoP learning. For instance, the role of the gatekeeper as an obligatory point of passage was captured in the following statement about an individual who held the power to allocate recourses to BW within the earthquake science CoP;

> *"I think it comes from the senior management at the moment, we have a Chief Executive who is very academic … he and people like him believe that doing too much listening to the community … as opposed to just thinking about where the science is going is a dangerous thing."*

Funding institutions were recognised as gatekeepers who held a high level of influence in whether boundary interactions would be facilitated or discouraged. Respondents reported being subject to the priorities of funders which often hindered boundary engagement such as a primary focus on publications in the science community, and outputs for beneficiaries in the humanitarian sector. Growing focus on the societal impact of academic science within UK Research Councils; however, demonstrates a potential for gatekeepers to also act in a capacity that encourages and supports boundary interaction. One can therefore see how gatekeeping may be interpreted as the management of CoP boundaries, the necessity of which is emphasised through McNie's [8]; p.26) assertion of the need to actively manage the socially constructed boundaries between science and decision making. This paper reinforces the concerns raised by scholars of the need to move away from intentional separation processes like social closure which Cash et al. [3] describe as 'extreme', towards management efforts that aim to achieve a balance between specialisation and boundary work.

4.5.2. Buffers

National organisations such as the British Geological Survey were found to play an influential role in the management of CoP boundaries, providing what Wenger [22]; p.237) describes as 'facilities by which outsiders can connect with their practice in peripheral ways'. As such, they could be seen to act at the periphery of the earth science CoP, providing a beneficial public service through the provision of educational resources, and a reputable point of contact for critical preparation

and mitigation information for times of crisis. Unlike academic scientists who identified their primary goal as the advancement of knowledge, all three individuals interviewed from BGS similarly described a *"duty"* to be a *"premier geoscience information provider"* and to produce *"science for the benefit of society"*. The existence of such a service; however, led some university-based scientists to suggest that BGS staff were in a better position to communicate earthquake science as an integral part of their job. They portrayed this as one of reasons for their own lack of boundary interaction, stating that they in contrast had to remain focused on objective research and committed to the tasks more conducive to success in the wider scientific community.

The analysis therefore uncovered a suggestion that the designation of a sub-group or peripheral space dedicated to boundary engagement could serve as a buffer to protect the core practice of the science community. This view is in keeping with Wenger's [22]; p.237) portrayal of periphery facilities as allowing for 'some boundary activities without overwhelming the community itself with the task of accommodating outsiders' demands'. Under this interpretation the ability for BGS staff to credibly take on a role reflective of Pielke's [28] science arbiter providing a resource to answer factual questions, may in turn allow the rest of the community to maintain a position more akin to the pure scientist. While this did not mean that university-based scientists could not engage at peripheries, there were instances where it seemed to ease their sense of obligation. Despite the perception among some scientists that BGS staff were in a better position to engage in boundary work, the three representatives interviewed in this study were not found to have any stronger links to humanitarian NGOs than their university counterparts. While recognising the valuable role played by organisations like BGS the paper questions whether the perspectives described above reinforce a view among academic scientists that BW is someone else's job, in turn sustaining a linear approach to knowledge sharing rather than a rich learning experience between social worlds.

4.5.3. One-off encounters

The predominant form of boundary interaction transpired as one-off encounters, with 19 scientists and 5 NGO practitioners reporting isolated instances of interaction that did not lead to sustained collaboration. These encounters primarily presented as unidirectional transfers of information, where scientists acted as one-off transferers and NGO staff as one-off receivers of knowledge. This transpired through workshops, scientific reports, consultancy and online blogs which typically detailed *"very basic … information particularly following big, damaging earthquakes"*. Humanitarian practitioners described engaging with science *"as required"*, with a typical response being *"we reach out and bring in the skills that we need as we feel we need them"*. An example of this was seen following the 2010 Haitian earthquake when scientists were brought in to explain the event to frightened NGO staff. Practitioners expressed difficulty in attempting to collaborate with researchers on a longer-term basis, explaining that their efforts *"usually end in consultancy"* where they have to pay scientists for their time.

The type of engagement experienced in one-off encounters was therefore most reflective of linear science communication carried out by Pielke's [28] 'pure scientist'. In keeping with scholarly critiques of deficit model approaches, there was awareness among scientists that such interactions did not present sufficient means of sharing learning. This was captured through one scientist's account of his participation at a science-NGO workshop where he recalls having no idea if the information he shared was beneficial or relevant;

> *"It was completely one way and it was me describing things, almost lecturing I guess, so I don't know how much use it was"*.

Despite indications that *"most of these things don't seem to be two way"*, there were instances where one-off encounters materialised as participation in bidirectional knowledge exchange events. With a focus on uncovering the potential for science-humanitarian collaboration, such gatherings allowed NGO practitioners to share the reality of their operations and information needs. Although iterative endeavours were found to foster an appreciation of the knowledge, intentions and priorities of the other CoP; singular interactions were more likely to illuminate differences and challenges to communication.

While one-off encounters presented as the type of boundary participation least conducive to building trust and sustained relations between CoPs; there were a number of reasons as to why it remained the most common form of interaction across the earthquake science-NGO interface. For instance, participants from both CoPs considered it less time and resource intensive, reporting a lack of incentives and rewards to justify longer term engagement. Furthermore, given that scientist's typically *"don't get training"* to communicate with NGOs, they reported drawing on the skills that came most naturally by replicating the means of sharing knowledge within their own communities.

4.5.4. Interlockering

Two individuals were identified whose interaction at the boundary interface was more substantial than a one-off encounter yet was not sustained enough to fit within the typology. Both were established members of their respective communities who acted as representatives on committees and advisory boards within the other CoP. Their occasional interactions enabled them to act in a capacity characteristic of what Sebba [37]; p.397) refers to as 'interlockers who act as bridges'. This introduced another distinct boundary working position to the typology which presented as a pair relation between an individual and an institution, and overcame some of the negative aspects highlighted in personal pair-style relations identified above. It was also possible to see how those who partake in outpost-style boundary working may act in an interlocker capacity by providing a personal bridging link between their institution and the other CoP.

5. Conclusions

Focusing on boundary interactions and framing boundary working as an inclusive process of social participation in cross-community learning; this paper has demonstrated the potential for a BW typology to shed light on the degree and nature of social interaction taking place between earthquake science and humanitarian-development NGOs in the context of DRR. While 12 individuals were found to be moving across the CoPs in modes fitting of the typology, the analysis uncovered a number of challenges associated with engaging in such sustained, iterative forms of boundary learning. Scientists reported difficulty balancing boundary spanning attempts with research, while there was a perception within both CoPs that partaking in boundary learning may impact upon their status within their own community. The analysis found funded projects to act as vehicles for BW in the short-term, while wider organisational support proved essential for those interacting in longer-term capacities. While investing in personal cross-CoP relations presented an effective option for BW interactions on an individual basis it was not necessarily sustainable at an institutional level. Exposing a difficulty in moving beyond KE and transfers of explicit knowledge the paper identified the existence of additional modes of boundary participation largely marked by lower levels of social interaction, with one-off encounters presenting the most dominant form. While this may present the least effective means of sharing learning, the numbers involved demonstrated that the majority of scientists interviewed had made attempts to interact with NGOs in some capacity.

The findings uncovered attempts to manage CoP boundaries through buffers and gatekeeping; in turn highlighting a critical role for those adopting gatekeeping functions to encourage BW through the provision of increased social and institutional backing. As such, the BW typology presents a potential starting point from which to gain a greater appreciation of the many forms BW can take in order to better support it in turn, while providing a tool for self-reflection of one's own interaction across boundary space. The transferable nature of the tool carries

broader applicability in addition to providing a baseline for exploration into the changing character of earthquake science-NGO interaction. Acknowledging that additional forms of boundary interaction may exist beyond the confines of this study; this paper seeks to act as a catalyst for further critique into the varying nature of social interaction at boundaries across diverse geographical locations and social contexts.

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Declaration of competing interest

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