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DOI:

[10.1080/19463138.2020.1759606](https://doi.org/10.1080/19463138.2020.1759606)

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Document Version

Publisher's PDF, also known as Version of record

Citation for published version (Harvard):

Hadfield-Hill, S, Horton, J, Kraftl, P, Antonio Perrella Balastieri, J, Ricardo Nogueira Vilanova, M, Alves Dias, R & Valladares Soares, P 2020, 'Spaces of interdisciplinary in/congruity: the coming together of engineers and social scientists in planning for sustainable urban environments', *International Journal of Urban Sustainable Development*. <https://doi.org/10.1080/19463138.2020.1759606>

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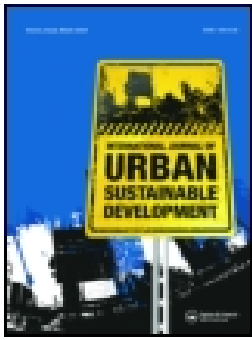
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To cite this article: Sophie Hadfield-Hill, John Horton, Peter Kraftl, José Antônio Perrella Balestieri, Mateus Ricardo Nogueira Vilanova, Rubens Alves Dias & Paulo Valladares Soares (2020): Spaces of interdisciplinary in/congruity: the coming together of engineers and social scientists in planning for sustainable urban environments, International Journal of Urban Sustainable Development, DOI: [10.1080/19463138.2020.1759606](https://doi.org/10.1080/19463138.2020.1759606)

To link to this article: <https://doi.org/10.1080/19463138.2020.1759606>



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Published online: 02 May 2020.



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Spaces of interdisciplinary in/congruity: the coming together of engineers and social scientists in planning for sustainable urban environments

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ABSTRACT

In the context of a globalised interdisciplinary moment, where boundary-crossing research collaborations are valorised, this paper considers encounters between multidisciplinary researchers. Presenting empirics and reflections from an international project where social scientists and engineers sought to collaborate, communicate and address complex challenges associated with sustainable urban development, we question a series of assumptions about interdisciplinary research. Importantly, we pause to consider the practical implications of *doing* this work. In particular, we draw attention to the spaces of interdisciplinarity, from the field to the lab and the meeting room, the role of researchers' reflexivity and positionality, and the importance of being aware of the embodied, emotional realities of such work. In so doing, we call for more critical, evidence-based reflection upon the lived in/congruities of interdisciplinary practices.

ARTICLE HISTORY

Received 8 October 2019

Accepted 18 April 2020

KEYWORDS

Interdisciplinary; engineers; social scientists; sustainable urban development; space; embodied; emotion

Preface: three little pigs, two ways of thinking

During a field trip to a municipal waste disposal site in Guaratinguetá, São Paulo State, Brazil, an Engineering Scientist tells a joke: 'Mr. Engineer prepares to read a bedtime story to a child. He begins by stating the fundamental conditions of variables p_1, p_2, p_3 as three distinct pigs. The story concludes that $Sp_1, p_2, p_3 = f(\text{straw, wood, brick}), \textit{Big Bad Wolf}$ '.

A Social Scientist replies that, in contrast, he could happily spend years narratively writing about the character, temperament, and habits of each little pig, and the banal, everyday practices, politics, social-materialities, emotional-affectivities and more-than-human spatialities that are extrasectionally-(re)constitutive of each of their 'home spaces' ...

Introduction

Across a wide range of contexts, interdisciplinary research has come to be powerfully valorised and incentivised by research funders, institutions and state, governmental and non-governmental agencies. From researching food security to population pressures on towns and cities, climate change, global finance, migration and natural disasters (World Economic Forum 2019), thinking and acting beyond normative disciplinary boundaries is increasingly understood as a vital precondition for social, economic, cultural and environmental sustainability (Ledford 2015; Stutchbury et al. 2015; Glatte et al. 2017; Trussell et al. 2017; Ganapati and Mostafavi 2018).

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Against the backdrop of this ‘interdisciplinary moment’, this paper reflects upon a networking project, which brought together Brazilian Engineering Scientists and British Social Scientists, to develop novel approaches in planning for sustainable urban environments. In doing so, it makes a series of key contributions to extant literature on interdisciplinarity and sustainable urbanism. First, it begins by offering a critical review of key assumptions of the internationalised ‘interdisciplinary moment’, highlighting some of the substantial hopes, expectations and ideals that are pinned on interdisciplinarity in this context. Second, the paper’s core argument is that while interdisciplinary research is centrally advocated by many national governments, research councils (see for example ESRC 2019; EPSRC 2019) and global agendas (World Economic Forum 2019), the practical *doing* of interdisciplinarity is rarely explicitly considered. So, whilst on the one hand interdisciplinary research is seen to ‘integrate insights from (unrelated) disciplines’ (Van Teijlingen et al. 2019, p. 1) and be a ‘process of boundary-crossing, mutual learning and co-creation’ (Glatte et al. 2017, p. S4721) how this works in practice is rarely considered and is often fraught with ‘methodological challenges’ (Glatte et al. 2017, p. S4721). Given this absence, we use empirics and reflections from our networking project to focus upon some particular moments of interdisciplinary exchange in the context of engineers and social scientists working collaboratively on key issues in the field of sustainable urban development. Fittingly, this project emerged from a funding call which explicitly sought to bring together social scientists and engineers, across cultural contexts to address a range of challenges related to sustainable urban architectures and infrastructures – to provide opportunities for integrated decision-making in designing, constructing and managing urban settings (Tsolakis and Anthopoulos 2015). We argue that there is clearly a need not only for more novel forms of interdisciplinary collaboration but for *careful and critical reflection* on the prospects for such alliances to address the thorny problems of sustainable urbanism.

Through a series of vignettes from the networking team, drawn from collaborative field visits in both the UK and Brazil, this paper reflects upon the embodied experiences of collaborative practices which emerged between engineers and social scientists. Whilst there is not scope in this paper to address in depth the ontological and epistemological framings of the

engineers and the social scientists collaborating in this project we do acknowledge difference – difference in our observations, calculations, understandings and representation of knowledge in the field of sustainable urban development. However, from a starting point of difference, we also hold a shared commitment to acknowledging and valuing ‘other’ knowledge in creating an interdisciplinary team.

On one level, the reflections in this paper suggest some of the everyday work, challenges and opportunities of bringing together a research team inclined and trained to think in terms of ‘ $p_1, p_2, p_3 \dots$ ’ (schemes, equations, symbols) with another inclined and trained to think in terms of ‘more-than-human spatialities *et cetera*’. However, the broader contribution of our paper lies where these reflections should have wider resonance for anyone seeking to do interdisciplinary research in practice, and especially in the wide field of urban sustainability. In this way, the paper highlights a series of collaboratively-authored lessons learnt from our encounters, which range from practical suggestions for constituting productive spaces of interdisciplinary work, to wider conceptual reflections upon interdisciplinarity *per se*. In particular, through our vignettes we build on Callard and Fitzgerald (2015, p. 112) who argue that a consideration of emotion and embodied practice is important in acknowledging the ‘affectively fuzzy domain’ of interdisciplinary work, arguing that much of what interdisciplinary researchers do ‘is learning to live through that fuzz.’ We argue that the present, grandiose ‘interdisciplinary moment’ tends to both underestimate the practical and conceptual challenges of *doing interdisciplinarity*, and to undervalue everyday, vital, although perhaps apparently, modest accomplishments of interdisciplinary work.

Contextualising the interdisciplinary moment: six assumptions

In the past decade, the notion of interdisciplinarity has come to be powerfully advocated and widely idealised in diverse international research contexts. In this *interdisciplinary moment*, interdisciplinary research is strongly valorised and internationalised through the agendas of most major research funders and institutions. For instance, it is now the case that interdisciplinarity is explicitly promoted by practically all of the UK’s major research funding bodies and learned societies (Petts et al. 2008; UK Government 2016; British Academy 2019). Thus, a joint statement

by the UK's major research councils articulates a central commitment to interdisciplinarity:

“as a part of its commitment to research innovation and ‘excellence with impact’, RCUK wishes to *support an enhanced culture of interdisciplinary and multidisciplinary research* in the UK and to ensure that its peer review and funding infrastructure is supportive of such work” (RCUK 2015, p. 1, our emphasis).

In this context, for instance, the UK's Economic and Social Research Council (ESRC) has promoted interdisciplinary research through programmes such as its *Development Frontiers* agenda, whereby ‘new approaches are needed that transcend and transect traditional boundaries – geographic, disciplinary and methodological’ (ESRC 2016a). Likewise, the UK's Engineering and Physical Sciences Research Council (EPSRC) articulates a central need to tackle the “complex UK and global challenges that require interdisciplinary approaches, such as Energy, Digital Economy, Technology Touching Life, Data for Discovery, and Urban Living’ (EPSRC 2019).

These interrelated turns to interdisciplinarity have constituted an unprecedented range of funding opportunities for academic researchers to foster, ‘pump-prime’, ‘seed’ or enhance interdisciplinary collaborations and networks. Indeed, this paper stems from a Research Council ‘Research Partnerships’ call, supported by the Newton Fund which directly requested ‘the development of interdisciplinary collaborations’ (RCUK-CONFAP 2015, p. 1). The scale of such strategic investment is substantial. For example, since 2015, the UK's Research Councils have ring-fenced £1.5 billion of research funding to deliver research aligned to ‘Global Challenges’ and associated problems in developing countries – with ‘sustainable cities and communities’ being a core, ‘intractable’ challenge highlighted within that scheme. Again, a prerequisite is one of “address[ing] global challenges through disciplinary and interdisciplinary research [...] to better understand the relationship between social institutions, physical infrastructure and the natural environment’ (ESRC 2016b, unpaginated).

Similarly, in the context of engineering education in Brazil, there has been a move towards interdisciplinarity. The Brazilian Ministry of Education has recently updated the National Curriculum Guidelines for undergraduate programmes in Engineering, with a stronger focus on promoting interdisciplinarity in

the education of engineers. Graduates are expected to be exposed to ‘activities that promote integration [with] interdisciplinarity ... implemented from the beginning of the course ... [encompassing] active teaching strategies, based on interdisciplinary practices’ (Ministry of Education 2019). The research funding landscape in Brazil has also seen a move towards internationalisation and interdisciplinarity (see for example the National Strategy for Science, from the Brazilian Ministry of Science, Technology, Innovations and Communications 2016).

Our ongoing research collaboration has, in large part, been a direct result of this agenda, in terms of the linking up of research councils (in our case the UK ESRC and the Brazilian FAPESP) and move towards interdisciplinarity. Within this internationalised *interdisciplinary moment*, six particular discourses of interdisciplinarity have been strongly (re)produced, to the extent that these assumptions perhaps now go unquestioned. First, it is widely assumed that *interdisciplinarity is necessarily an intellectual, social, political, scientific and economic good*. The value of interdisciplinary research – in tackling contemporary social-political-scientific-economic challenges, fostering new ways of working, and generating new modes of thought – is widely praised and anticipated. Interdisciplinarity is figured as a precondition for generating reliable, novel evaluations of complex problems (Isaksson and Karlsson 2006; Wickson et al. 2006), and building societal capacity to address such concerns (Jahn et al. 2012). In the realm of planning for sustainable urban environments, an interdisciplinary approach is deemed necessary to understand the intertwined challenges that face urban environments. Whether it be understanding interconnected flows of water and energy production and consumption or the linked challenges of resource conservation and management, the urban is seen as a site of multifaceted sustainability challenges or ‘wicked’, intractable problems that require considerable innovation (Howarth and Monasterolo 2016). Indeed, Petts et al. (2008, p. 594) argue that ‘the urban environment constitutes precisely the kind of “problem” deemed suitable for an interdisciplinary approach.’

Second, developing this latter point, *interdisciplinarity is understood as a panacea for complex social-environmental problems*. Often, interdisciplinary research is, essentially, charged with *solving* major matters of social-environmental inequality, harm, damage, conflict and degradation. This somewhat

salvational apprehension of interdisciplinarity is apparent in the way in which many national governments, research funders and non-governmental actors (World Economic Forum 2019) explicitly position interdisciplinary research as a key, *solution-orientated*, front-line response to ‘wicked problems’ or ‘global challenges’. Discourses around interdisciplinarity can thus often reproduce an anticipation that interdisciplinary research will (or perhaps should) be grandly, plurally and substantially impactful. This argument can be questioned on a number of fronts – not least in reflecting on the complex, fraught, unpredictable, often non-linear ways in which research ‘impacts’ come about, and how these are often intimately entangled with the production of apparently ‘frivolous’ or ‘pure’ theoretical insights (e.g. Horton and Kraftl 2005).

Third, we note that such hopes are particularly pinned upon the *coming-together of researchers from the social and natural sciences*. Within the imaginary of the interdisciplinary moment, it often seems that interdisciplinary work between social and natural scientists is understood as a kind of de facto ‘gold standard’ of interdisciplinarity (even where in reality most forms of interdisciplinary collaboration take place between cognate disciplines). Certainly, this sense is explicitly reproduced within the strategic aims and parameters of many recent major research-funding schemes (RCUK-CONFAP 2015; FAPESP 2017). Thus, a logic of first *characterising* and then *combining* ‘hard’, objective scientific expertise (e.g. around materials, flows, systems) and complementary ‘softer’, subjective social scientific ways of working (e.g. in relation to experiences, emotions, intentions and motivations) has come to be a prevailing motif of many calls. Yet, as we argue below, these assumptions have rarely been subject to detailed scrutiny – not least in term of their implications for the practical *doing* of interdisciplinary research between social and natural scientists.

Fourth, typically, *calls for interdisciplinarity constitute an implicit hierarchy of ways of working*. Thus, interdisciplinarity is understood to comprise a wide range of research practices (British Academy 2016):

- from individual researchers selecting and using methods or texts that are outside their normal area;

- to exploratory or challenge-focused collaborations between research groups around shared interests/problems;
- to the emergence of research communities which are characterised by their bringing together of diverse expertise in new configurations (of which Digital Humanities is an oft-cited example).

Similarly, interdisciplinarity is widely figured as part of a spectrum of research relationships:

- from isolated specialist, mono-disciplinary or subdisciplinary silos;
- to longstanding patterns of multidisciplinary research, with isolated disciplines studied without little interconnection or, perhaps, ‘different disciplines coming together, (typically around real-world “problems”), but with each group primarily working within its own framings’ (Petts et al. 2008, p. 596);
- to pluridisciplinary encounters which comprise cooperation between disciplines but without coordination or lasting change to established disciplines and hierarchies;
- to interdisciplinary practice, with new, sustained modes of knowledge production, synthesis, dialogue discussion and co-production ‘in-between’ extant disciplinary formations;
- to entirely new transdisciplinary ways of thinking and working which transcend, and fundamentally question, established disciplinary boundaries (Max-Neef 2005; Petts et al. 2008).

Frequently, these terms are imagined as an evolutionary sequence or series of milestones, with researchers exhorted to progress along this ‘continuum’ (Max-Neef 2005) or to ascend this ‘pyramid’ (Hadorn et al. 2006) towards more and more innovative, ambitious (perhaps iconically and inspirationally novel) modes of inter- and trans-disciplinarity (Klein 2004; Russell et al. 2008).

Fifth, *new forms of combinative systems thinking have become prominent*, constituting new interdisciplinary languages and points of connection. In the context of (urban) water management, for example, Integrated Water Resources Management (IWRM) promotes the coordination of water and land to maximise economic

and social welfare, in an equitable manner, whilst considering the ecosystem as a whole (Hering and Ingold 2012). Elsewhere, the Water-Energy-Food (WEF) nexus has become a rapidly-developing point of articulation for developing shared approaches to interdependencies between water and energy resources, including their negative and positive externalities (World Water Assessment Programme 2014). Indeed, 'nexus studies' have become a widely-used trope for articulating relations, interconnections, tensions and opportunities between water, energy and food (e.g. Belinskij 2015; Howarth and Monasterolo 2016). However, several studies have questioned the theoretical novelty and political vacuity of nexus-thinking (Leck et al. 2015; Cairns and Krzywoszynska 2016). A key charge is that such approaches simply valorise interdisciplinarity and the development of methods to *empirically* witness complexity without more deeply reflecting upon the geopolitical and sometimes neo-colonial logics that underpin calls for nexus approaches to sustainable development.

Sixth, in this context, it is widely assumed that *meaningful interdisciplinarity can be readily accomplished* through investment in networking, joint work programmes and collaborative practices. Co-presence, above all, is often imagined as a necessity to productive interdisciplinary working relations. Many large-scale research investment programmes have thus prioritised the facilitation of encounters between individuals and groups from hitherto disparate disciplines. This faith in the productive capacities of the (funded and programmatic) interdisciplinary encounter further imbues spaces of interdisciplinarity with an intense degree of hope and expectation (to which, perhaps, one can never live up?). It does not, however, afford a sense of the multiple ways in which interdisciplinarity might proceed – whether through other forms of 'contact' than co-presence, or through encounters that might not be contrived through funded, programmatic, even 'formal' mechanisms.

The ongoing turn to interdisciplinarity has constituted all manner of exciting spaces, conversations and opportunities. Certainly, our own lives, careers and research interests have been enriched and challenged through unprecedented opportunities for interdisciplinary research. Moreover, interdisciplinary working may constitute novel and vital spaces of research practice in tacking together previously-siloed diverse approaches to globalised research priorities. However, while the rhetoric of interdisciplinarity has never been stronger, there is an attendant need to further

critically reflect upon the six assumptions presented above. Specifically, little scholarship has reflected on the challenges of *doing* interdisciplinary work – especially across diverse disciplines such as human geography and engineering, and across international contexts. Therefore, in taking up this considerable challenge, this paper develops some more critical, practice-focused, evidence-based reflections upon the present interdisciplinary moment.

Practice-based reflections and learnings from a networking project

The remainder of the paper presents a series of vignettes to highlight the opportunities and challenges of actually *doing* interdisciplinary scholarship. In order to unpack the in/congruities of interdisciplinary work, these vignettes are presented around two spaces of interdisciplinarity: i) the field; and ii) the lab/meeting room. To set the context for the following vignettes, it is necessary to give a brief background to the networking project, which underpins this paper.

Sharing Futures was conceived to address key challenges in planning for sustainable urban environments, by bringing together two teams of researchers who in their respective disciplines have significant track records of research in sustainable urban development (Hadfield-Hill 2012; Kraftl et al. 2013; Balcazar et al. 2013; Sampaio et al. 2013; Nogueira Vilanova and Balestieri 2014, 2015; Vilanova and Balestieri 2014, 2015; Horton et al. 2015; Vilanova et al. 2015; Vilanova 2015; Christensen et al. 2017). Bringing together a team of engineers from Brazil and a group of qualitative social scientists from the UK, the newly-formed project team embarked on a series of focal field trips, exchange visits, workshops and a summer school to foster interdisciplinary discussions around sustainable urban development.

The Brazilian team comprised of mechanical engineers, water resources engineers, electrical engineers and geologists with technical research expertise in energy and water resources management. By contrast, the UK team were qualitative human geographers interested in everyday experiences and interactions with built environments, primarily informed by qualitative, participatory and ethnographic research principles. Both groups of researchers began from a point of openness to knowledge sharing and stepping outside disciplinary 'comfort zones'. For the Brazilian team,

this was articulated in terms of the importance of bringing social, cultural and environmental subjectivities into the modelling, analysis and verification of inherently complex, dynamic, uncertain real-world systems, to better support technical, political and institutional decisions around sustainable urbanism. For the UK team, the project was seen as an opportunity to develop skills in working with scientific peers in order to generate theoretical and methodological tools for understanding complex physical systems that could improve community participation and education about sustainable urbanisms.

The network of researchers developed three core project activities in relation to water and energy resources in urban development. First, the team engaged in a process of sharing data and research findings from previous projects, compiling research summaries and collating a bank of transferable exemplars in addressing water and energy problems in urban development (see: <http://www.sharing-futures.com/NEWS.php>). Second, through a collaborative process, the team explored innovative uses of a mobile application in researching the water/energy nexus – designing, developing and testing the tool for future research in the field. Third, a series of capacity-building activities, beyond the research team, in both the UK and Brazil, was organised by means of summer schools, group work, observational field visits, virtual calls and workshops, spaces to enable discussion and the stepping outside of our disciplinary and cultural frameworks. In 2016, during one of our project networking events, group discussion focused on the disciplinary, linguistic, cultural and institutional challenges of doing interdisciplinary research:

- Language/semantics of disciplines;
- Time constraints of often short networking/research grants (pressure from funders);
- Diverse practices within the academy on the authorship of papers (i.e. in the social sciences it is common just to have a few people as authors on papers versus large engineering teams);
- Theory and the framing of findings (assumptions about shared knowledge);
- The risk of innovation and what if it goes wrong, in the era of metrics and UK Research Excellence Framework (REF);
- Epistemologies – assumptions / pre-conceptions / fundamental differences in ways of working.

Summary notes
(Sharing Futures Summer School 2016)

To a large extent, the above challenges are symptomatic of the *temporary* nature of much interdisciplinary work (Albert et al. 2017), which has been designed to ‘address a specific mission or deliver a particular outcome’ (2017, p. 1). From the above notes, which mention diverse practices, different languages and divergent theories and knowledges, *time* is needed – time to get to know, time to understand, time to think; this type of work jars and rubs up against the fast research landscape that characterises increasingly neo-liberal forms of academic knowledge production (Vostal 2014). Here then we take a distinct juncture from the challenges outlined above, to explore in more detail what it looks like and feels like to do interdisciplinary work. Through our focus on *doing*, we aim to contribute a more nuanced discussion of the ‘*politics of knowledge production*’ (Trussell et al. 2017, p. 2). In preparing this paper then, each member of the team reflected on the process of *doing* interdisciplinary work in this networking project. Figure 1 is a visual representation of interdisciplinary work, thinking through the variables of discipline, culture, space and the researcher.

We suggest that this matrix could be used as a starting point for thinking through some of the intersecting variables involved in the doing of interdisciplinarity, key aspects of which we expand on and exemplify in the subsequent sections of the paper. For scholars embarking on an interdisciplinary funding proposal, or beginning conversations with new teams, this matrix could be a guide for thinking through your own work. As we have already shown in the section on contextualising the interdisciplinary moment, much of the literature has focused on disciplinary ways of working which is ‘structured by a configuration of power relationships among disciplines, epistemologies and competing definitions of academic excellence’ (Albert et al. 2017, p. 3) as well as the recent shift to cross-cultural interdisciplinary collaborations. As a departure from previous writing on interdisciplinarity, we focus on the spaces where this happens in practice. First, we consider the field as an enabler and second think through what it means and feels like to be in each other’s everyday workspaces (such as the lab). We build on Trussell et al. (2017, p. 2) to address the ‘emotional sensitivity’ of interdisciplinary research. In doing this, we prioritise the researcher – their motivations, confidence, experience, bodily capabilities and senses – in order to articulate some of the many variables involved in the *doing* of interdisciplinary research.

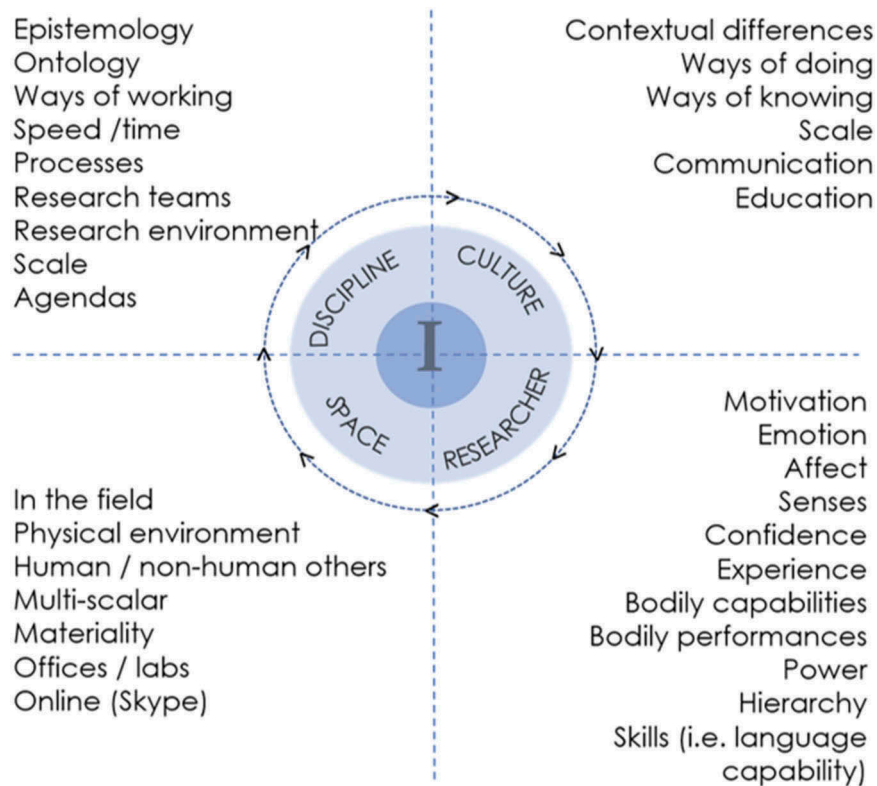


Figure 1. 'Doing interdisciplinary research'.

The field as an enabler of interdisciplinarity

During our networking project, a series of field visits were organised in both the UK and Brazil, designed to prompt discussion and comparison between our diverse ways of working in the field of sustainable urban development. It was through our being together in these spaces, our walking around them, our talking and seeing together, that a greater understanding of processes of sustainable urban transformation was enabled. Being in the field mattered in the shaping of the interdisciplinary encounter.

'I remember standing on a hillside near Campos do Jordão looking at a section of rock/soil exposed by a landslide. I have some geological knowledge so 'knew what I was looking at'. But I really admired and valued the way the engineers were able to look at the rock, touch the soil, and quickly analyse and narrate the processes, pressures and flows which had constituted it ... just the clarity and logic with which they could tell me what happened, with the help of a few explanatory sketches made in the dust on the floor, using a twig. Also how they were able to distil really complex processes into a manageable and comprehensible

narrative. So with just a few sketches, they could tell me how soil, rocks, vegetation, geological faults, termites, water pipes, illegal water supplies in informal communities, settlement densities, corporate agricultural cropping practices, drainage channels, regional utilities governance etc etc were interrelated' [Author, Horton].

In the above vignette, one of our social scientists reflects on being in the field and struck by the methodical explanation which our engineering colleagues gave to the landforms, process and implications for sustainable urban development based on their ontological and epistemological grounding of knowledge (a core aspect of 'doing interdisciplinary research' as shown in Figure 1.). Here we would argue that being in the field, together, helped to break down barriers to disciplinary thinking and narrate complex engineering and social processes. For us, undertaking these fieldwork visits together helped us to all understand the context of the social, physical and technical processes associated with sustainable urban development evidencing contextual differences. Being in the space together enabled us to get a stronger grasp of

the entanglement of a diverse range of human and non-human actors, whether they be the soil, rocks, drainage channels or termites which were mentioned above, all of which play their part in the construction (and sometimes destruction) of sustainable urban development.

Here it is also important to acknowledge the intricacies which being in the field offers, prompting multi-scalar discussions about the design, management and governance of sustainable urban development. Standing in the field, as in the vignette above, we look down ‘at the rock [and] touch the soil’ as well as look out over the valley and wider ecosystem of urban development, infrastructures and land slippages. On another visit, we stood at the edge of a municipal waste disposal site and together thought through the impact on the paddy field, which lay in the valley. The wider geographical context for our field visits – looking at landscapes *together* – facilitated new discussions about the interrelations between engineering and social science. It was these discussions and drawings of flows and interconnections with sticks in the mud, in the field, which provided a starting point for developing a joint understanding of the nexus in sustainable urban development. It was the bringing together of social scientists and engineers, *in the field*, which helped us to appreciate the complexities of sustainable urban development, and opened up our thinking about the interconnections between food, water and energy. The conversations, questions, drawing, looking at, imagining and framing of landscapes developed our thinking about nexus relations and sustainable urban futures.

The next vignette, from another of our team, reflects on a field visit in the UK. The aim of this visit was to share findings from previous social science research on the everyday experiences of living in a new housing development that had been designed to facilitate social and environmental sustainability:

I had done this tour at least 20 times with my undergraduate students, policymakers and other social science colleagues. We began to tread our usual route, highlighting the key findings from our research – past the Code Level 6 eco-homes, on to the playground, round by the square and into the mews. This time with the engineers it was different – a different speed, different questions, a different feel. A particular stand out moment for me was when one of the Brazilian team bent down to the pavement and touched the slabs. He then went on to explain the science of the sustainable urban drainage system. I had walked over

these slabs hundreds of times and never thought to look down’ [Author, Hadfield-Hill].

We use this vignette to highlight further points about the value of being in the field together, as social scientists and engineers. First, some contextual information is needed. This sustainable urban extension was built in response to the UK Labour Government’s commitment to *Sustainable Communities* housing policy. Owing to high land prices, there was a tendency to build either on brownfield, ex-industrial sites or on ‘green’ sites. In particular, many of these new housing developments have been built on floodplains, meaning that significant planning and design measures have been introduced to mitigate against flood events. One key measure has been the introduction of Sustainable Urban Drainage Systems (SUDS). These integrated water management systems combine a number of features including roof drainage, permeable street surfaces, swales, drainage ditches and retention ponds. They are considered more effective at the scale of the watershed, rather than individual neighbourhoods (Montanari et al. 2013); however, as a result of the piecemeal nature of much urban development, neighbourhood-level drainage management systems are more common.

This vignette draws attention to further points about interdisciplinary working – that of the sensual and the assumptions about knowledge. As insinuated in the vignette the UK team had worked on the case study site for many years and they had led over twenty ‘guided walks’ for other colleagues, practitioners and young people – however, never with engineers. As the vignette highlights, this time ‘it was different.’ Within a few minutes, the engineers were kneeling on the floor, touching the pavement surface, asking questions about permeability, water flow, and the swale system: this was a point of congruence. Up to this point, the social scientists had been interested in the social interactions with sustainable urban technologies; the engineers were interested in the form, functions and workings of the same system.

Being together prompted us to use our bodies in different ways. This reminds us of work by Paterson (2009) on haptic geographies, who draws on Merleau-Ponty (1992) to argue for a more sensory appreciation of fieldwork – to think of our bodies as an ‘elastic sensory-spatial envelope’ (Paterson 2009, p. 777). In other visits to field sites, the questions we were asking

of each other prompted a different sort of interaction with the site. Soils, rocks, pavements, fruits and water were touched (and sometimes tasted), we encouraged each other to move our bodies in different ways – to bend, to look down, to look out (across landscapes), to look over, to go down low, to go up high. So being together prompted both the engineers and the social scientists to look at places in different ways. Being in the field together made us see and feel the field differently.

Our visit to this site also enabled the engineers to more fully appreciate the social complexities of designing sustainable communities and the importance of ‘the social in engineering new urban developments,’ as shown in the vignette below. This development was heralded as an exemplar of sustainable urbanism (TCPA 2007), with Code Level 6 houses designed into the development, with criteria for insulation, air permeability and passive solar input to name a few features (DCLG 2010). The social scientists gave detailed accounts of children and their families’ interactions and the everyday complexities of living with such eco-technologies. For the engineers, being together in the field gave them the occasion to reflect on the consequences of designing technologies which may on the one hand have technical, economic and environmental credentials but fall short socially in terms of knowledge and use.

Our visit to the project in Northampton, accompanied by social scientists showed us the realities of bringing together diverse construction types, different aesthetics and energy-efficient buildings to work towards environmental as well as social sustainability. This trip really highlighted the importance of the social in engineering new urban development [Author, Balestieri]

Again, it was the benefit of being in the field, together, which prompted stories, narratives and showcased the complexities of socio-technical living and the challenges facing engineers in planning for environmentally sustainable solutions. The guided walk, for the engineers, encouraged them to think of difference, acknowledging that technologies for sustainable design need to encompass diverse knowledges and diverse users, as well as designing in difference to technical solutions to sustainability. The next example comes from our visit to the Centre for Disaster Risk Management in Brazil:

The engineers had arranged for us to all visit CEMADEN, the Centre for Disaster Risk Management in Sao José dos Campos. This was an extraordinary visit, to see first-hand how environmental disasters are predicted and mitigated from the national to the local scale. This room was emblematic of the need for interdisciplinary thinking and talking – working in the context of disasters needs diverse knowledge, cooperation, trust and communication – across disciplinary boundaries [Author, Hadfield-Hill].

It was here that as a team we really appreciated the ‘need for interdisciplinary thinking and talking’ – the control centre at all times was manned by a core group of people with diverse disciplinary backgrounds, including engineering, geography, geology, meteorology and social science. Not only did this field visit bring in to sharp focus the importance of this collaboration but it also drew our attention to the scalar importance of interdisciplinary working. In several of our previous vignettes, we have shown how an appreciation of multi-scalar framed many of our field visits, from appreciating the granular nature of soils rubbed between our fingers, to looking out over the farm and over the valley. Having geographers on the team, we are already attuned to thinking through scalar implications of our research. However, it was our interdisciplinary encounters that made us appreciate the multi-scalar and multi-political dimensions of sustainable urban development. The social scientists were taken beneath the ground, to think about the pipes, networks and flows, and implications on diverse regions and people.

There are two further points about *being in the field* that we would like to make. In the above vignettes, we have shown how particular moments prompted interdisciplinary discussion and congruity. However, and redolent of earlier feminist critiques of the notion of ‘the field’ (e.g. Amit 2000) for us the ‘field’ extended well beyond the field itself – our discussions and thinking continued in the weeks, months and indeed years after these moments. Our being-together in these spaces provided a moment of congruity, which gave a hook for thinking through the complexities of sustainable urban development, and importantly a hook for relationship building, a point that we will return to in the next section. The final point about *being in the field* is the wider context of Global Challenge-led research, which we find ourselves operating in. For funding by the major research councils in the UK (and, increasingly, elsewhere), researchers have to show how their research is ODA (Official

Development Assistance) compliant, with an assumption that knowledge and – and as – ‘aid’ is uncritically transferred from the minority north to the majority south. From the inception of our project, we designed these fieldwork moments in both countries, and saw the field as an enabler of interdisciplinary learning, across diverse contexts. For us, being in the field *together* prompted a way of working that pushed our thinking and opened up opportunities for collaboration and congruity.

Being in each other’s spaces – the lab and the meeting room

To extend our thinking further about the actual doing of interdisciplinary work we turn our attention to being in each other’s everyday working spaces. In reflecting on social scientists and humanities academics working in the medical profession, Albert *et al.* (2017, p. 2) argue that ‘existing scholarship on interdisciplinarity has not sufficiently emphasised that the meeting of disciplines always occurs within social spaces that are neither neutral nor sheltered from power struggles.’ In this section then, we present three vignettes, which build a picture of how interdisciplinary work happens in practice. There are a series of key points which emerge: i) the place of emotion in doing interdisciplinary research; ii) learning to be flexible with different working styles; and, iii) working beyond interdisciplinarity. In the following vignettes we can see how important the coming together of different researchers is in making interdisciplinary research happen – the researchers come to the project with different levels of experiences, different bodily capabilities, emotional registers and degrees of confidence, to name but a few variables (see Figure 1). However, before we talk about physically being in the spaces, of the lab and the meeting room, it is also important to highlight virtual space as a facilitator of international collaborative work. The initial phases of our collaboration – getting to know one another, sharing expertise, and planning our funding applications – took place via Skype and email. We had monthly Skype meetings, where the whole team would meet and discuss progress and plans. Of course, there were substantial benefits of this, enabling us to hold relatively quick meetings, sort out problems and develop our international working relationship with relative ease. However, not surprisingly we battled with poor internet

connections, complications with time zones and difficulty with interpretation (contextual, language and disciplinary). These online meetings were vital in grappling with the practicalities and emotionalities of our interdisciplinary work; but more so was the physical coming together of the team.

Emotion was a key thread in our team vignettes, thus it is important for us to acknowledge the emotional labour involved in interdisciplinary work. Indeed, in a similar vein, Callard and Fitzgerald (2015, p. 113) have found ‘the labour of interdisciplinarity is emotional in ways that depart from the regular affective challenges that accompany all collaborative endeavours.’ In their reflections, they argue that it is ‘not enough to focus on epistemological differences between disciplines ... we are not simply describing here, interdisciplinary situations in which a researcher feels confused because she does not have the knowledge base to understand the content of a collaborators communication’ (2015: 114/115). However, we would argue that to a large extent the emotional work involved in our interdisciplinary work, did stem from this – the epistemological chasm between our worlds of understanding, presentation and language. In the following vignette, a social scientist in the team reflects on these feelings of difference in attempting to close the epistemological gap:

‘Right, so we are now in a lab – it has science written all over it. From the lab coats hanging on the back of the door, some machines at the side of the room, the configuration of the tables and chairs, this is a science space. I have to say, slightly scary and intimidating.

Then the presentations began ... the last time I saw graphs, equations and maths like this, I was at school. My brain doesn’t work this way, my palms are sweating, heart racing what does all this mean? How does it relate to what I know about sustainable urban environments? (Author, Hadfield-Hill).

From this vignette, we can make several points about the emotional and embodied labour involved in interdisciplinary work. First, it is inherently spatial and space matters when thinking through the impact that interdisciplinary work has on the research team. In this example, the team were in a scientific space, there were ‘lab coats’ ‘machines’ and the tables and chairs were arranged in a particular way. So to a large extent, the epistemological chasm is widened through the materials the team encounters and the spatial arrangement of such equipment. For those in the team who are not familiar with such

environments, this can be 'scary and intimidating.' The vignette then moves on to show the epistemological chasm more clearly and the impact on those outside of the discipline. The presentation put together by the engineers was littered with 'graphs, equations' and mathematical references – one in which prompted a bodily reaction with 'palms sweating' and 'heart racing.' The feelings associated with being 'out-of-place' in interdisciplinary research are very real.

Whilst, as researchers, this may have jolted our ways of thinking and ways of being together, it encouraged an understanding of each other's work, an understanding which was based on the premise that actually we did not have to fully understand, but more importantly, to facilitate an epistemological awareness of difference. In a similar vein, Trussell et al. (2017, p. 5) reflect on the vulnerabilities and insecurities felt when stepping outside of disciplinary boundaries, finding that their 'own emotionality [was] overwhelming as each of [them] independently, questioned the value of [their] contributions to the project.' Thus, as we embark on interdisciplinary research, it is important to acknowledge the affective impact of how this works in practice, and indeed the spaces in which this happens. In the following vignettes, we show what it felt like to be in each other's spaces, bringing with us our own disciplinary practices and ways of facilitating knowledge construction:

'This process of collaborative meetings, in our different spaces, with different materials has challenged my pre-conceptions about social science research. Our ways of thinking and working were so different ... I was confronted with a form of analysis distinct from the one to which I am accustomed, with different worldviews and perceptions of the ones that are normally part of the analysis and interpretation structures that I perform in other types of problems studied by myself and my students' (Author, Balestieri).'

'It was interesting to realise how taken for granted ways of working for social scientists (e.g. extensive group discussions; feeding back ideas to the group) were uncomfortable and unusual for engineering colleagues. I noticed that they tended to stay quiet, make lots of notes and really plot out their comments before opening their mouths' (Author, Horton).

The first vignette from an engineer, reflects again on the different materials used in meeting spaces, and comments 'I was confronted with a form of analysis distinct from the one which I am accustomed.' Here he is referring to the ways in which the social

scientists led a workshop during the course of the project. Armed with flip chart papers and pens, small group's discussion commenced, discussing issues related to sustainable urban development. However, it was this relatively banal act of getting out the flip chart paper which made engineers feel uneasy. For them, this was a new method, a new way of working. As the vignette above describes, this moment was noted by a social scientist in the team, noticing that during these group sessions facilitated by social scientists, 'they [the engineers] tended to stay quiet, make lots of notes and really plot out their comments.' Thus, being aware of each other's emotional sensitivities and awkwardness is important – as together we are navigating this interdisciplinary moment. Indeed, our working together has shown us that emotional sensitivities are an important aspect of interdisciplinary work that should not be underestimated.

Given our insight above, we argue that a consideration of the material *and* social spaces of everyday work is vital for more fully appreciating how interdisciplinarity works in practice. However, a final point to note comes from the vignette below. In this case, the social science researcher reflects not on the work being done together, as a team, but on the spatial layout of the engineer's office and the practices imbued in their professional life:

'It was interesting to experience meetings and see life in a Brazilian university engineering dept. I enjoyed meetings in Jose's office. The way he and others talked about the 'zones' of their offices ('a place for thinking, a place for solving problems, a place for meeting' or something like that) is actually something that has helped me work more effectively in my own office. I was also touched by the Brazilian team's daily afternoon coffee meeting: lovely to see a team who get on that like that' (Author, Horton).

Reflecting on the lab as a space of scientific work is somewhat predictable when reflecting on our experiences of being in each other's spaces. However, it was not just the labs that prompted a discussion of difference, as in the vignette above; our office spaces and how we use them were also different. Via our Skype meetings, we had seen our respective offices virtually, and we had had glimpses of the books on the shelves, the computers and the plants on the window sill. However, it was physically being in the department, *in* those offices (and labs), which added to our interdisciplinary encounter. In the vignette, the researcher comments that the engineers worked in 'zones ... place[s] for thinking, place[s] for solving problems,

place[s] for meeting[s].’ The organisation of the engineers’ offices contrasted with those of the social scientists, who had not formalised different ‘zones’ in their offices and where the functions of different parts of their offices were defined in blurrier ways (if at all). Although to an extent these observations reflect personal as much as they do disciplinary differences – and of course the availability of space within an office – these observations nevertheless lead to an interesting point about what we take away from interdisciplinary working. As well as the new knowledge, relationships and ideas, we also take new forms of working in ways that may appear somewhat banal, but which are central to the patterning of different embodied professional practices. It is important to understand and recognise these patterns, since they may striate our ways of working, both together and as independent researchers in our own disciplines. The final point in the vignette brings us back to the emotional sensitivities of doing research together, which may not be a disciplinary practice but cultural; it was the *daily coffee meetings*, as a space to get to know one another which were important in providing the grounding for future collaborations and ideas. Significantly, the researcher perceived this as something to be admired – something ‘lovely’ – and, as a result, the social scientists considered how they could incorporate similar spaces and times of sociability into their own working weeks.

Conclusions: lessons learned through the coming-together of engineers and social scientists

Our networking project emerged as part of an interdisciplinary moment – a moment characterised by international agendas, government funding requirements and policymakers calling for the coming together of disciplines to work towards solving some of the grand challenges of today. It was in this context that our team, of engineers and social scientists, from Brazil and the UK respectively, came together to begin a conversation about addressing some of the key challenges associated with sustainable urban development.

From waste management to sustainable urban drainage, urban systems are complex and it is thought that to understand and find solutions to complex challenges, boundaries need to be crossed. Such boundary-crossing is in turn complicated by

processes of knowledge-production: from the formulation of research questions, to fostering dialogue in the search of synergy, to the elaboration of future public policies that may transcend disciplinary silos. However, in practice, interdisciplinary working is hard to do (Evans and Marvin 2004).

Previous literatures on interdisciplinarity delineate that many of the struggles of interdisciplinary research stem from our own understanding of disciplinary silos, what is impact, cultures of knowledge creation and disciplinary epistemologies (Schoenberger 2001). These variables are often cited in the literature (summarised in Figure 1 – under discipline) and are often given as reasons for this type of research being riskier, more time-consuming and in the long run a more expensive investment (Shove and Wouters 2005). However, there is scant literature available on the actual *doing* of interdisciplinary research, and particularly the everyday, emotional considerations thereof. This paper therefore constitutes a significant contribution to debates about interdisciplinary working, particularly in the wide field of urban sustainability research. We do not simply acknowledge but exemplify and critically analyse Albert et al.’s (2017, p. 3) contention that ‘the reality of interdisciplinarity is therefore often far from the fantasy depicted in the literature and in professional discourse: a disembodied meeting of open minds occurring in neutral space and enabling the free pursuit of complex problems.’ In extending that work, in this paper, we have proposed a greater focus on the multiple intersections and variables associated with interdisciplinarity in practice. Through our vignettes, we have focused on the importance of space and the researcher’s embodied experiences to showcase why thinking through interdisciplinarity in practice matters (summarised in Figure 1).

In the context of our relationship as engineers and social scientists, and in coming together to write this paper and reflect on the practice of interdisciplinarity, we end this piece with two core points of consideration for anyone currently working in or embarking on an interdisciplinary project. First, be willing to reflect on your academic ‘self’ – your positionality – and try to retain a sense of humour in doing so. Being open to reflection is vital in interdisciplinary working, in the development of a mindset open to other perspectives and ways of being and doing. There are assumptions about how each discipline thinks and works, but our working together has challenged some of these

assumptions. In the case of our team, the engineers have often been more reflective than the social scientists, which is interesting, given the purportedly 'more' reflective disposition of the social sciences. The engineers have been open about what it means to be an engineer – in essence, critically reflecting upon both themselves and their disciplines in ways that the social scientists had not. Being aware of the numerous *researcher* variables (often intersecting) which are at play in interdisciplinary work, such as motivation, emotion, affect and power (see Figure 1), will go some way to understanding the dynamics of your team. In doing this, being open to the deconstruction of self and discipline will enable a reconstruction of the team and, ultimately, of interdisciplinary collaboration – through the process of opening up, laying bare what we do, why and how we are feeling about it.

Moreover, in all interactions, humour is important; laughing at ourselves was a vital part of deconstructing our-selves (the 'three little pigs' joke cited in the Preface was one of these moments). On the topic of humour however, we feel we need to make a point about the coming together of our two teams. We often reflect that we were lucky to find each other – two teams of researchers with a similar sense of humour, a group of people that like to be in each other's company. Much of this cannot be forced or contrived. In our experience, our collaboration was fostered via a networking opportunity – an opportunity to be in each other's company (both virtual and physical), to discuss our intersecting research interests and to get to know one another (and laugh). It was using this foundation that we built a strong team who could trust and collaborate with one another.

Second, being aware of the importance of space in enabling (or indeed disabling) interdisciplinarity is vital. For us, space was a crucial factor in shaping how our interdisciplinary work happened in practice through often emotional and embodied encounters. The field visits which we each planned in our respective countries opened up conversations, new lines of thinking, enabled an appreciation of each other's disciplines and challenged perceptions about each other's work in the field of sustainable urban development. For us, the field was an enabler and prompted us to think differently about how we engage with some of the complexities that faced us. However, it was not just the field that prompted us to think differently – it was being in each other's

everyday working spaces, in each other's labs, meeting rooms and offices that played a role in the deconstruction of the self. Being open and honest about the sharing of knowledge and experiences in these spaces was an important part of our working together.

Doing interdisciplinary networking and research is at once challenging and rewarding. We have contributed to burgeoning literatures on interdisciplinarity through questioning a series of assumptions about interdisciplinary working and pausing to consider why we need to be aware of the disciplinary, cultural, spatial and personal variables which come together in the *doing* of interdisciplinary work. In doing this, we have offered a critical lens on the practical exigencies of sustainable urban development research, in this interdisciplinary moment.

Acknowledgement

The authors of this paper would like to thank the RCUK-CONFAP 'Research Partnerships' networking call and the ESRC for funding this project (ES/NN004663/1). As a research team we continue to collaborate - develop ideas, push our thinking and importantly, laugh with one another.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Economic and Social Research Council [ES/N004663/1].

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