

Cultivating critical practices in physical geography

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Fundamental changes in the meaning and practice of environmental science are affecting – and are affected by – the theoretical, technological, pedagogical and institutional projects of physical geography. These changes have given rise to a range of ‘integrative’ (or integration-directed) disciplinary narratives which articulate a role for physical geographers within an engaged project of societal relevance and transformation. In this context, we welcome the rise of a notional ‘Critical Physical Geography’ and here we seek to expand the conversation to support thinking about what it might mean to be critical *within* physical geography. Moving beyond definitions of interdisciplinary collaboration, we propose that being critical from within physical geography begins with cultivating a critical disposition towards the situated partiality of our scientific practices. This prompts consideration of the ways in which our environmental objects could be assembled differently, reflecting different personal histories and values, and from different epistemic locations and management framings and through different investment narratives. A critical disposition prompts reflection upon the situated constraints and opportunities presented by our institutional locations. Recognition and articulation of critical perspectives may provoke endeavours to more consciously reassemble our scientific and institutional projects into more effective interventions to secure a more powerful and meaningful role for physical geographers across their diverse engagements.

KEY WORDS: Applied geography, environmental science, epistemology, institutions, pedagogy

Introduction

Dramatic transformations in practices and institutional framings of physical geography are underway. These transitions reflect longstanding and ongoing concerns for disciplinary profile and identity, exemplified by the development of ‘environmental science’ in the 1970s (e.g. Brown 1970) or emerging engagements with Earth System Science (Pitman 2005; Paola *et al.* 2006; Richards and Clifford 2008). Recent developments also reflect dramatic changes in access to (and sharing of) information, and associated technologically framed ways of seeing, measuring and valuing the world. For example, new instrumentation and measurement techniques, explosions of data availability and enhanced computing (analytical) processing power have markedly increased our capacity to develop increasingly sophisticated numerical modelling applications (Church 2010). At the same time, greater appreciation of the values of divergent metho-

dologies, interdisciplinary practices, multiple lines of evidence applications, cultural considerations, and communication strategies have come to the fore (e.g. Yeager and Steiger 2013). These framings increasingly recognise that human-caused aspects of environmental change cannot be viewed as empirically separable from the observed operation of environmental systems (e.g. Zalasiewicz *et al.* 2011; Palsson *et al.* 2013). Beyond this, remarkable advances in the mobility of practices and applications in our increasingly inter-connected world have brought about much broader societal framings of scientific practices, provoking greater appreciation of the socioeconomic, political and cultural underpinnings of our work, and their institutional framings (Clifford 2009; Lane *et al.* 2011; Tadaki *et al.* 2012). This has heightened awareness of concerns for appropriate transferability of understandings, the importance of place, and how we relate the specific to the general (e.g. Phillips 2007; Brierley *et al.* 2013). These transitions present a host of opportunities for appropriately

grounded geographic endeavours. Biophysical enquiry is increasingly differentiated across a spectrum ranging from specialisation in geophysically based technical applications to applied (geographic) problems, with differing perspectives, options and trajectories associated with different investment streams, norms, challenges and rewards. New approaches to enquiry and synthesis are required if biophysical assessments are to meaningfully and substantively engage with social processes in order to understand (and live equitably with) environmental change.

In light of these developments, Lave *et al.* (2014) call for the formal development of 'Critical Physical Geography' as a subfield within Geography. In this vision, Critical Physical Geography promotes 'Integrating the power relations and social processes at the heart of critical human geographic inquiry and the material processes at the heart of physical geographic inquiry' in a wider project of social and environmental transformation (Lave *et al.* 2014, 6). Lave *et al.* argue that the complexity of human–environment problems can only be meaningfully and substantively appraised and addressed through integrated inquiry into social and environmental change. In this framing, the 'environment' becomes problematised as a purely social or biophysical domain, and interdisciplinary cooperation and reframing is promoted as a valuable pathway forward (see also Harden 2012; Lane 2014; Ziegler *et al.* 2013). Lave *et al.* (2014) further elaborate that a 'critical' component of physical geography is essential to this – rather than approaching interdisciplinary cooperation in an instrumental fashion, it should instead be approached as an engaged political project, in which environmental processes are explicitly linked to particular social practices, thereby enabling contestation, critique and change of those practices (e.g. do capitalist processes produce distinctive biophysical landscapes?). In this framing, the role of physical geographers might be imagined as 'revealing the real', but couched within a critical framework developed by critical human geographers.

While we support the general ambition of Critical Physical Geography as an explicit *subfield* as articulated, in this paper we seek to extend the proposition for a 'critical' physical geography as a political *project* to engage all physical geographers in conversation about the links between values, science, and environmental outcomes. We highlight two opportunities for articulating such a wider project.

First, we wonder whether an 'integrationist' or 'middle ground' framing of Critical Physical Geography might be limiting where it could (and perhaps should) be empowering to all physical geographers. In particular, we would like to ensure that the opportunity to *be critical* in physical geography is not limited to being an 'optional interdisciplinary extra' to be undertaken by a few physical geographers of a

particular inclination, or attached to a small portion of nominally 'interdisciplinary' projects. Not all scientists are willing or able to dissociate from their academic networks in order to work directly with communities or social scientists in an experimental context, as some argue is necessary (cf. Lane 2014; Ziegler *et al.* 2013). There is a need to develop and support thinking about 'criticality' that includes and empowers physical geographers across a broad range of epistemic interests and institutional locations.

Second, we are concerned about the 'integrationist' metaphor of explanation – integration implies fixity, prospectively reproducing nature/culture categories and suggesting or promoting single 'integrated' or 'comprehensive' endpoints. This could be interpreted as implying a universality which may be anathema to developing critical reflexivity about how environmental science is enactive of *specific* and *value-laden* social processes and outcomes. Thus, rather than thinking about a 'critical' project as one which embraces a particular style of interdisciplinary co-operation, we contend that practices should also cultivate a critical disposition to the value-laden assembly of environmental science, problem framings, and notional solutions. Such thinking recognises and draws out the contingent values that are practised through environmental science, making these framings explicit so that new worlds can be more democratically imagined and assembled (see Proctor 1998; Latour 2004).

In this paper we encourage a broader, reflective and enactive framing of 'being critical' in physical geography. We take as our starting point the observation that scientists are already skilled and effective at critical thinking in the sense of being sceptical of claims and exploring multiple lines of explanation (Haines-Young and Petch 1986; Cox 2007; Wolf *et al.* 2010; Inkpen and Wilson 2013). Being critical begins with a disposition and a situated understanding of the scientific categories, theories and techniques, research relationships, political economy and pedagogical contextualisation of environmental projects. Rather than providing a 'critique' of the status quo institutional forms, we approach being critical as a mindset with which to understand the situated character of environmental practices. As a mindset, it promotes situated understandings, responses and actions (and their effects and affects). In another sense, however, being critical is also about embedding a kind of 'situated partiality' into our understandings and practices across multiple sites, from the field to data analysis and 'all the way up' to management and investment frameworks. We take from this an existing disposition to understanding the situated, contingent and emergent character of environmental explanation, and we seek to expand the scope of political action available to physical geographers by linking the ontological, epistemological and institutional dimensions of their work.



Thus, rather than viewing 'critical physical geography' as a formal relationship between environmental science and critical social theory, we attempt to open up what 'being critical' might mean *within* the institutions and practices of physical geography.

We suggest that such possibilities could be built around a systematic reflexivity about the nature of our scientific practices – where they come from, how they evolve, and recognition of the kind of work they do. From this we can begin to think more directly and constructively about how to enact different kinds of environmental practices. In this sense, we propose a way of thinking about *being critical* in physical geography that is open to all physical geographers, whether they choose to engage with critical social theory or not. What possibilities emerge from reframing physical geography in new, *critical*, ways? What are the sites and mechanisms through which a 'critical' physical geography might be practised? How are we organising ourselves to develop new and 'valuable' lines of thinking in research, or to empower students (to what ends)? How are we reconfiguring our relationships to our work by imagining our practices as connected/ing to local and global knowledge formation, circulation and action?

The paper proceeds as follows. The second section outlines some important features shaping the meaning of scientific practices in physical geography, and argues that physical geographers are active agents in the re/production of these meanings. The third section considers 'being critical' as a *disposition* with which physical geographers can begin to question their engagements in politics across a range of sites and kinds of practices. The fourth section argues that a critical disposition is not enough to change the world, and offers that critical reflection should be coupled with engaged *enaction* of new practices and politics. The fifth section concludes that a 'critical' physical geography presents an important opportunity to develop a broad and inclusive project that is oriented towards exploring and remaking the politics of practice in physical geography.

Contextual considerations that underpin practices in physical geography

The practices (normalised sets of procedures and meanings) of environmental scientists and environmental science are not simply about 'representing the real' (Inkpen and Wilson 2013). If anything, we can at least say that it is about 'representing the real' of something *from somewhere*, and perhaps by *someone* with a specific set of theoretical underpinnings and values. All geographers have in various ways encountered what might be described as a 'politics of the biophysical', which assumes that the practices of environmental science are simply about representing what is real, and are thus immune to critique from non-scientific viewpoints (Tadaki *et al.* 2014). While

we do not seek to revisit debates about social nature here (Castree and Braun 2001; Demeritt 2009; Tadaki *et al.* 2012), and following Lane (2014), we think that others will accept that:

- Outlooks and perspectives on scientific (geographic) practices are influenced by personal and institutional experiences, histories and training (see Oughton and Bracken 2009). Situated framings engender particular preferences and positionalities that underpin our practices, despite the inherent quest for independence, rigour and replication.
- There is a political economy to research – research requires investment by actors and organisations, and not all concepts, framings, methods and models are created (and circulated and embedded) equally.
- There is an increasing focus on method in physical geography – emphasising 'skills' such as mathematical and computer modelling, instrumentation advances and the application of tools within Geographical Information Science (recognising the notional power of objectivity and universality that these tools yield, and the privileges given to the processes and scales that are specified).
- There is a strong focus on 'application' and 'integration' in environmental science, which is disciplining the style and form of knowledge to encourage approaches and 'packages' which transfer insights across space, or order them into specific theoretical-political containers, such as Earth System Sciences, Ecosystem Services (Potschin and Haines-Young 2011), risk derivatives (Randalls 2010), and so on.
- Opportunity costs of teaching and research framings are often not explored and engaged. For example, do emphases upon methodological developments and techniques come at the expense of emphasis upon explanation and critical inquiry (with attendant alternate skills development)?

The recognition that environmental science is innately partial and that it is shaped by societal institutions is well established within physical geography (e.g. see Inkpen and Wilson 2013). Moving beyond the model of scientific falsification as the path to absolute knowledge, an embrace of critical realism has emerged over recent decades as a way to become sensitised to the personal methodological and ontological dispositions of scientists, and the implications that these have for what is known and acted upon. We are not simply observing or revealing the world as it is, but rather we are revealing parts of the world and interpreting them through particular lenses (Odoni and Lane 2010). However, to date, much of this 'epistemic situating' has entailed identification and articulation of the theories or personal preferences of scientists. We feel it is important to extend these understandings and framings,

broadening the scope of critical discourse in physical geography to include the politics of institutions (Inkpen and Wilson 2013:4). With these issues in mind, we think the emergence of a 'critical' physical geography offers a powerful opportunity to think more broadly about the *work of our practices*, as a way of bringing politics from 'out there' to 'in here' (Le Heron and Lewis 2011; Tadaki *et al.* 2012).

As researchers, educators and institutional actors of various kinds, physical geographers are *actively* engaged across many sites and forms of knowledge production and enactment. We are housed in organisations such as universities, research institutes, government departments, consulting firms and schools, through which we encounter structures that constrain and enable certain kinds of ideas and certain kinds of practices. As institutional subjects, we have significant capacity to consider what kinds of subjects we want to become, the purposes we wish to fulfil, and how we want to go about such endeavours.

We feel that there is emancipatory potential in considering prospects for a more explicit critical turn in physical geography, and in imagining how our practices connect to others. To us, this requires more systematic engagement with the institutions (and politics) of physical geography. How are agendas set and norms established within our departments, and our subfields? In many cases, restructuring academic life requires embracing new categories and arrangements – funders, 'users', return on investment, managerialism, application potential, citizen science, sustainability agendas and so on. External factors surely influence our practices, but they do not necessarily inhibit new (innovative) approaches. How we narrate and practice these factors then proves important in enabling different kinds of interactions and pathways to unfold. With this in mind, we argue that a critical project for physical geographers might be built through reflecting on the political constitution and framing work of scientific practices, and the recognition that we are *already* enacting certain kinds of ideas, framings, values, politics, and that we may want to enact different kinds of ideas, framings, and discourses in different ways. This kind of 'critical' project blends the reflexive elements of the critical scientific tradition with an orientation to enacting values and politics through our work as knowledge producers.

To resist, reform and embed different narratives of environmental practice into institutional and investment trajectories requires engagement with the historically and socially situated practice of power. In developing capability to do environmental science differently, we need to think about contextual constraints and assets that shape the nature and style of interventions which are likely to gain traction. While narratives of 'Mode 2' (Gibbons *et al.* 1994), 'postnormal' (Funtowicz and Ravetz 1993) and 'sustainability science' (Kates *et al.* 2001) framings all

affirm the presence of expanded notions of 'peer communities' beyond the purely scientific, substantive mechanisms have yet to be proposed or enacted to consider the *politics of the biophysical* and how values are problematically *assembled through* – rather than external to – environmental science (e.g. see Greenhough 2012; Bracken and Oughton 2013).

The recent approach to 'critical physical geography' outlined by Lave *et al.* (2014) provides one valuable way in which this can happen. However, we argue that much can be articulated with respect to 'being critical' from *within* physical geography. Simply, we do not feel that institutionally contextualised scientific practices must necessarily emerge through physical geographers gaining direct familiarity with critical social science (and associated theoretical underpinnings). Having said this, we recognise explicitly that awareness of divergent perspectives on our work is valuable and worth folding into conversations. However, in contrast to critical physical geography and the other narratives of integration, we emphasise the need to explore the realms of action available to physical geographers in their various institutional locations, and the ways in which their practices interact with and remake the world. Ours is a simple and pragmatic question: how can one be critical *in* physical geography?

Being critical in physical geography – orientations to knowledge production

We do not see 'being critical' in physical geography as an end state, but rather as a commitment to *cultivating* a reflexive disposition to our knowledge of the world and then *acting* through it (e.g. Lane *et al.* 2011). Thus, rather than developing a bounded definition of 'critical physical geography' based on formal interdisciplinarity (i.e. environmental + social science) or a political definition based on key theoretical concepts, we feel that there is value in recognising that contexts are multiple and that the ways in which physical geographers can and perhaps should be 'critical' ought to engage with multiple institutional and agency contexts (see Inkpen and Wilson 2013; Lane *et al.* 2011). While our following discussion draws examples from within the academy, we intend the argument to be of broader relevance. Indeed, we hope that the discussion reveals our method of understanding the 'situated partiality' of our engagements and opportunities.

Developing a critical disposition to the practice of environmental science builds on a particular conception of politics which it is important to clarify. We approach 'politics' as any articulation involving propositions (made in diverse ways) about how the world ought to be. Fundamentally, politics is about choice: if (desirable) environments can be structured

or revealed differently, then we face choices among possibilities and the problem of *which ways of knowing* environments ought to be promoted, circulated, embedded and acted upon. Reflecting upon how choices are constitutive of values and preferred *means* and *ends* is required to support enquiry into the role of environmental science in intervening in (and contributing to) discussions about environmental management and governance (see also Lane 2014).

In cultivating a critical disposition *within* physical geography, we begin with three recognitions.



Environmental science as political practice

The first recognition is that environmental scientific concepts, methods and practices are constitutive and enactive of politics. The categories, metaphors and techniques we use to make sense of the world bring with them all sorts of contingent assumptions about environmental processes and human values (Larson 2011; Phillips 2012). Figure 1 illustrates this concept in the context of environmental modelling, in comparison to narratives of 'integration'.

The practice of modelling environmental systems often involves modellers/scientists who build, run, and narrate the models, and decisionmakers/end users. Traditionally, these groups are conceived as operating in two disparate spheres of activity with little communication between them, where 'best science' informs model development and the decisionmakers insert 'social values' into the process from the outside of the modelling process (i.e. a *politics of the biophysical*). Figure 1(a) highlights how integration narratives propose substantive overlap between the communities, and seeks to legitimate a range of new concepts and practices as they relate to the process of scientific inquiry. While these new practices are valuable and enable discussions about the means and ends of environmental science, we feel that this narrative leaves 'retreat space' for those non-interdisciplinary scientific practices to go unquestioned. In an 'integrated' modelling project, for instance, there will still be aspects of model building that are relegated to 'scientific judgement' and which are not understood to influence the politics of decisionmaking.

In contrast, Figure 1(b) places scientific practices at the centre of political reflection, and understands that values-based decisions are also being made *within* the modelling process, as key choices about how environments should be understood and acted upon are being made under the guise of expert knowledge. There are substantial issues with communicating inherent complexities and uncertainties that underpin the precision of quantitative model predictions of environmental systems to managers. Key questions include:

- Should the system be modelled at all, or might other approaches be appropriate?
- Should a single or multiple models be used (Chamberlain 1965; Schumm 1991)?
- What *type* of modelling is desirable?

These are not just theoretical questions, and they have material implications. Some argue that natural systems may be too complex to allow meaningful quantitative modelling (Cooper and Pilkey 2004; 2007), advocating an approach to management that combines an examination of past patterns of environmental change and the use of expert judgement to assess likely future change at a given site. Should we rely on the judgement of experts and associated subjectivities, or is it preferable to use a numerical model that is known to be imperfect, but provides a capacity to manage complexity in a systematic framework (Dickson *et al.* 2009)? Similarly, there are material stakes involved relating to decisions about model validation (e.g. assessment of how accurately a model reproduces observed dynamics or system behaviour) or verification (e.g. assessment of a model's structure). Application contexts shape the available expertise, cost, ease of use and the importance/value of local knowledge that are each considered (or understood) to be relevant to a particular environmental problem. Such contexts are not necessarily 'set'; they can be tested and intervened in dependent upon situational constraints and opportunities.

The scientific practices of environmental modelling extend beyond 'representing the real' (Inkpen and Wilson 2013), folding into their conduct particular narratives about how models are useful and how environments can (and should) be acted upon. Ironically, while modelling is often justified in scientific, investment and management circles as a way of 'accessing the inaccessible' (to paraphrase Lane 2011), practical actions based upon model outputs are often criticised as prescriptive and in some cases unethical (Mahony and Hulme 2012). Hence, great care must be taken when considering the transferability of understandings, relating local circumstances to general (theoretical) principles (Brierley *et al.* 2013). Even if a modeller is aware of the various limitations and uncertainties associated with a model prediction, those tasked with making management decisions may not place the same weight on epistemic uncertainties relative to other motivating rationalities, such as cost, transparency, repeatability, ease of use, and so on. Thus whilst the acts of modelling and decisionmaking might be distinct, decisions around what and why we model must be understood as *political practices* concerned with articulating societal means and ends.

In framing rivers, coasts or atmospheres as knowable and model-able deterministic numerical systems, we legitimise certain kinds of inquiries, ideas

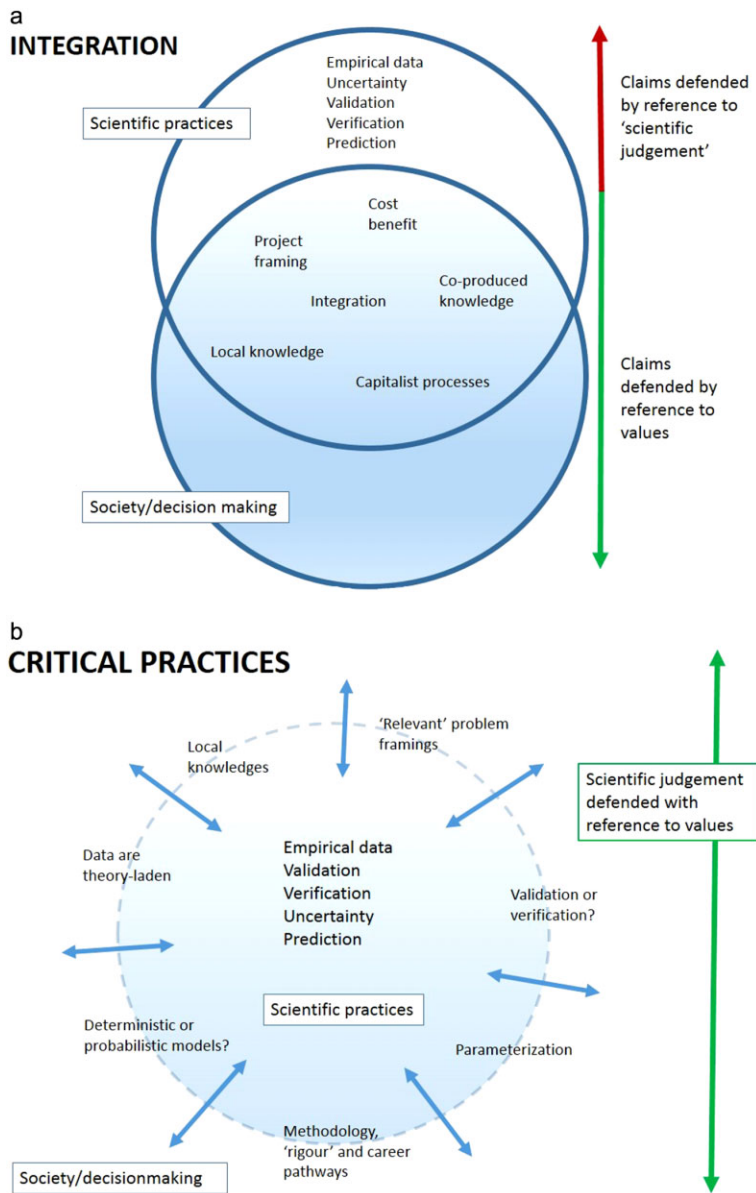


Figure 1 Comparing integration and critical practices approaches, through an example of scientific modelling. (a) *Integration* narratives enable new conversations, but can still leave a ‘retreat space’ for expert judgement. (b) A *critical practices* perspective seeks to understand how modelling practices are constitutive of values and societal means and ends.

and methods; and we act upon systems in particular ways. This prompts questions about *who* the representation benefits relative to other kinds of understandings. Further, as peopled ‘things’, ideas and methods can be thought of as situated, invented, promoted, stabilised, constructed, reformed, institutionalised and resisted. For example, climate change adaptation models have been exported into development contexts in order to govern/validate the

use of aid funding, and – because local users are not allowed to modify the models – they commit communities to developmental trajectories defined from the ‘centre’ (Mahony and Hulme 2012). Similarly, flood inundation modelling practices have been shown to be biophysically simplistic, yet such practices direct major investments into flood prone areas, thus creating heavy path dependencies and narrowing the scope of future action (Lane *et al.*

2011). While for years the *politics of the biophysical* has functioned to separate these questions from the concern of the environmental scientist, it has now become clear how the scientific practices we pursue are constitutive of many different kinds of meanings and interests (Tadaki *et al.* 2012; 2014). This prompts us to question: How have I come to these scientific concepts and theoretical frameworks? What work are they doing? Which other relationships are they trying to legitimise, and with what effects and affects? What kinds of human subjects do they assume and reinforce?

Organisational contingency

The second recognition underpinning a critical orientation in physical geography is that the situated configuration of organisational structures and incentives presents particular constraints and opportunities for engagement and action. The ways we structure departments and research groups, or promote certain activities over others, influences the bridges we build and the kinds of traffic that flow across them (Box 1; see also Oughton and Bracken 2009). Increasingly visible concerns are arising around how we imagine interdisciplinary practice and distinctions between positivism and post-positivism, qualitative and quantitative research, gender equity and performance assessment, etc. (e.g. Sharp *et al.* 2011; Clark and Steelman 2013). This highlights the importance of a *situated* understanding of our organisations along multiple axes and a consideration of the *practical dynamics* which fashion what is possible (Clark and Steelman 2013). In pursuing different kinds of environmental research questions,

we need to think about our capabilities: which kinds of collaborations, which kinds of pursuits, which kinds of investment trajectories, which kinds of categories? Rather than seeing these as set constraints, these considerations can be viewed as *opportunities* or *resources* with which to tell powerful new (and contextually progressive) stories about how environmental processes (should) matter.

Pedagogical practice

The third recognition comes from opening up the politics of pedagogy. To date, the primary questions around pedagogy in physical geography have been about which skills and/or methods are useful or relevant to various employers of graduates (e.g. Church 2005; Parsons 2006). In this sense, the answer to the question 'what kind of physical geographers do we want to train?' has been expressed in relation to 'skills that are considered to be desirable in the market place'. Normative and political questions about these aims have largely been taken for granted. However, are we convinced that physical geographers should be trained to use methods (defined by the preferences of their teachers) to simply 'understand the environment better', or do alternative approaches promote deeper engagement with the complex, emergent world of environmental science? Is the merit of a particular model in its R² value, or does value lie in appreciating and understanding how problems are framed? How we teach and engage with these discussions fashions perceptions of the world that our students will work within, and the ways in which they feel they can contribute to differing situations. Effective practice entails much more than rote learning or prescriptive

Box 1 Behind the scene aspects of research practice

Invisible agendas, choices and events may affect the process and reported outcomes of research. Particular 'people, rooms and places' may drive research agendas forward. For example, it may be instructive to consider the following questions in assessing team membership and roles for a collaborative research project:

- Who puts the team together?
- How are members chosen? Where are they from? Who do they 'represent'?
- What is their institutional setting (university, government agency, consulting company, etc.)?
- What stage in their career are members at (promotion and tenure pressures)?
- How have they been influenced by their pedagogic trajectory?
- How is the work divided between members? Which parts are sub-contracted out?
- What are the rules of engagement? How are divergent perspectives expressed and reported? Are processes and practices self-selecting and self-reinforcing?
- Is there scope to reappraise core questions and terms of engagement? How are such processes managed?
- Who collates the information, ascribes priority, relevance and importance to the data?
- Who packages (frames) the results, to serve what purposes (promote publication and citations, satisfy existing funding agencies or justify future research grants, steer public opinion or government policy, promote career aspirations)?

Such considerations may influence the trajectory of the research as much if not more than transparent controls expressed by funding agencies.

tick-box exercises. Creativity and innovation emerge from effective (grounded) knowledge (whether formalised or otherwise), commitment to experimentation, and a deeply embedded capacity for independent critical thinking (alongside attributes such as 'instinct', 'intuition' and 'presence'; see Sauer 1956; Spronken-Smith 2013). Such provocations prompt questions about the re-framing and holistic contributions physical geographers might make in *diverse* settings, and how we can operationalise alternative approaches and practices (e.g. Brierley *et al.* 2013; Church 2010; Legates *et al.* 2011; Malanson *et al.* 2014; Martin and Johnson 2012).

Reframing 'politics' in physical geography

These recognitions suggest the need to move thinking beyond 'application' discourse in understanding the work of physical geography. We are not arguing that physical geographers should *become* activists *per se*; rather, we contend that physical geographers are *already* acting across these various fields of enquiry and engagement (i.e. they are already political actors). Personal career and identity projects serve to link our scientific, institutional and pedagogical projects. These, in turn, are linked with (and are moulded by) the projects (and politics) of others. By viewing our starting points as already political, we can consider how coherent our engagements are across different sites; how our projects relate to the work of others; and how our projects fit in with much wider thinking around science-society and political economy concerns. Beyond these contextual considerations, we can also think about how we 'perform' our work in these and other arenas, and begin to reflect on the work that our performances do in turn, with students, with colleagues, in the world. Crucially, we do not just act these things out in a natural or disembodied way. We use our values to assemble propositions about the world, and each time we perform these propositions they gain strength, are reshaped, give effect to (or weaken) other things, and so on. Hence, it is important to appraise not only our awareness of factors that fashion the politics of our scientific framings, but also to consider how our practices can reshape these institutions in turn. As such, there is a need to explore some of the sites and mechanisms through which we reflect on *and* enact different environmental narratives.

Cultivating reflective and enactive practices

Cultivating a critical disposition to our work is a crucial step in opening up possibilities for a situated and engaged environmental science. This entails answering a simple question: where do our practices come from, and what work do they do? There are both historical and contemporary elements to this question, and from these a third might be opened up: what kinds of practices do we want for what kinds of work in the future?

Table 1 illustrates a range of sites through which physical geographers make choices and 'do politics' through their work. While sites such as departmental research agendas are generally a well acknowledged feature of politics *per se*, the relationships between 'scientific practices' and the more obviously 'social' concerns (such as hiring practices) are not often recognised as sharing the common work of institution building, and performing and embedding environmental framings. Table 1 highlights the important distinction between being critically *reflexive* about how institutional factors can shape the content and meaning of our practices, versus developing new and critically *enactive* practices which seek to shape the content and meaning of institutions. A critical project for physical geography should not be about divesting responsibility of our framings to that of 'institutions', but it should be about taking responsibility for approaching our practices as constitutive of arguments for a better world (e.g. see Tadaki *et al.* 2014).

While a critical disposition helps to identify choices and value commitments, it should also be understood within a wider spatio-temporal framework of knowledge production. For this, we will need verbs and metaphors to understand and communicate how environmental science is multiply constituted, multiply changing and multiply understood; how it is a series of situated and grounded theoretical, methodological, institutional, personal and governmental propositions and projects with their own networks, momentum and contingencies.

In addition to cultivating a critical disposition, we suggest that engaging with *enaction* entails thinking about practices of reframing, mobilising and reassembly (Table 2). These verbs draw attention to the different modes and mechanisms through which we can understand how environmental science and commitments to particular choices (i.e. politics) might be reconfigured. Consideration of the origin and prevalence of particular 'problem framings' encourages thinking about how scientific categories and narratives connect to wider discussions about the means and ends of environmental management (Wesselink *et al.* 2013). Networks and contingencies contribute to the *mobilisation* and recirculation of particular concepts, methods and approaches, and the work they perform in different settings is important to unpack (McCann and Ward 2013). Which investment narratives, scientific methodologies and career pathways do these ideas resource?

Thinking about networked mobility as a resource enables us to consider how to *mobilise* concepts, tools and frameworks into different settings, and how to build longitudinal connectivities and momentum around new and more reflexive and democratic framings.

Finally, *reassembling* offers a more nuanced account of the practices of environmental science than (say) integration, because it highlights the

Table 1 Cultivating reflective and enactive practices in physical geography within the academy

Sites of politics	Situated reflection	Enactment
<p>Emerging institutional frameworks determine:</p> <ul style="list-style-type: none"> • Disciplinary alignment • Staffing policies • Collaborative work • Mentoring philosophies and practices • Investments in technologies and networks • Reconfiguration of research/teaching roles 	<ul style="list-style-type: none"> • How do institutional frameworks shape our perspectives? • How are we building disciplinary and methodological projects? • How does promotion, prestige, reputation affect our choices? • How are teams framed and how do they work (see Box 1)? • How do applied scientists imagine and enact their responsibilities for outcomes? • How are employment practices shaping which environmental narratives are told and strengthened? 	<ul style="list-style-type: none"> • How do we develop practices and frameworks that apply multiple methodologies? • How do we ensure divergent threads of enquiry are pulled together in a meaningful way? • How are we securing disciplinary practices in physical geography? • How do we scope and secure future opportunities?
<p>Scientific practices and measurements are shaped by:</p> <ul style="list-style-type: none"> • Ontological complexity – systems are emergent, nonlinear, contingent • Recognition of performativity: scientific practices reinforce particular framings of environmental problems • Use of modelling applications and scientific tools for environmental management 	<ul style="list-style-type: none"> • How are the purpose and methods of investigations derived? • Are framings prescriptive and deterministic or open-ended? • How do we appraise the spatio-temporal representativeness of what we measure? • Should uncertainty be formalised or internalised? • How do we assess the appropriateness of different approaches (see Box 1)? 	<ul style="list-style-type: none"> • How should we frame and navigate the benefits, tensions and limitations of differing methods? • How should we relate the local and the theoretical (general)? • Can we develop multiple lines of ontological reflexivity into our teaching and research? • How might we develop new (open ended) metaphors for our scientific practices?
<p>Research agendas are increasingly shaped by:</p> <ul style="list-style-type: none"> • Managerialist orientation (outcomes and ‘impact’ driven) • Citizen, postnormal and ‘Mode 2’ science • Open source technologies and new media, commissioned or applied science • Planning ‘toolkits’ which homogenise space and time • Need to narrate value through ‘crisis’, framing science as <i>necessary</i> for action 	<ul style="list-style-type: none"> • What roles do funding mechanisms play in enabling or restricting visionary and proactive practices? • How do path dependencies ‘lock in’ particular scientific approaches, with what effects? • How are ‘relevance’, ‘impact’ and ‘success’ measured, and with what effects? • How do we manage external relationships (e.g. with industry and agency partners)? • How do past engagements shape current investment and research imaginaries? 	<ul style="list-style-type: none"> • Can we enhance critical thinking in research practice through changing research agendas? • How might we perform a ‘critic and conscience’ role in commissioned and applied work? • How can we move beyond placing caveats on the use of scientific applications to engage more directly with the production of new environmental management framings? • Can we assemble networks of people, projects and methods in order to <i>expand</i> and <i>reframe</i> future narratives of ‘impact’, ‘relevance’ and ‘value’?
<p>Teaching agendas are being reimagined:</p> <ul style="list-style-type: none"> • Course content and delivery • Protocols for treatment of epistemic and ontological ‘Others’ • Moral, scientific and societal relevance of science • Use and framing of emerging technologies • Engagement with ‘real world’ issues 	<ul style="list-style-type: none"> • What capabilities do we have to (re)frame teaching agendas? • Which epistemic ‘selves’ are we producing through our teaching within our specific institutional contexts. How have these practices come about? • How are these ‘selves’ engaging with others and with what effects? • Is our teaching methods-focused and/or problem oriented? 	<ul style="list-style-type: none"> • In what ways are teaching agendas ‘constrained’ and how might these be creatively navigated? • How can we cultivate enactive thinking through situated learnings about real world issues with multiple methodologies? • What mechanisms might be used to reflect upon and reframe teaching agendas as required? • How are we training physical geographers to <i>add value</i> to multiple kinds of conversations, beyond a methods or technological focus?

Table 2 Four modes of critical practice

Practice	Definition and action
Disposition	A disposition of situated partiality acknowledges plurality in biophysical environments and their measurement, as well as plurality in <i>approaches to</i> analysis of landscapes, atmospheres, ecosystems, etc. Such thinking is attentive to the ways in which environmental science is put to work to inspire certain forms of action.
Reframing	This involves actively exploring different ways of understanding the environment ('the problem') and different ways of understanding how approaches inspire actions ('the solutions'). Endeavours highlight the links between values and scientific practices, to deliberate more openly about societal means and ends
Mobilising	The mobilisation of environmental problems, rationalities, tools and solutions into new spaces and conversations, reconfiguring local relations along the way. This prompts consideration of how and through whom environmental narratives travel and gain traction (and might do so for democratic ends)
Reassembling	Reassembly entails building networks of concepts, frameworks, colleagues, problem framings, methodologies, investment trajectories and institutional narratives into coherent projects to enable new pathways of action. A concern for 'emergence' recognises that issues and situations are likely to take very different shapes and trajectories in different settings and circumstances. Such engagement promotes and engenders situated institution-building and reflexive adaptation through ongoing appraisal and restructuring

situated, relational and networked 'pulling together' of elements into a set of propositions about the world. Rather than presenting a singular 'integrated' outcome, we feel that emphasis should be placed upon the act of assembly, recognising how different worlds could have been (or should be?) reassembled. Such thinking focuses attention beyond 'comprehensive' or 'integrated' research as an endpoint, promoting deeper responsibility for the specific *qualities* of partiality in scientific research, and their associated values, framing effects and implications.

Although we find these heuristics helpful for thinking about *being critical* in physical geography, we are also acutely aware that Tables 1 and 2 present a particular set of intellectual and institutional conditions, concerns and commitments, and that others may find different verbs and metaphors more helpful. Indeed, recent dialogue between physical and human geographers in our School has certainly energised the direction and detail of our thinking (Le Heron and Lewis 2011; Blue *et al.* 2012; Tadaki *et al.* 2012; Brierley *et al.* 2013), and this carries a particular emphasis on understanding – and enacting – the value of a physical geographical disciplinary identity.

The development of a conceptual vocabulary for understanding and debating the normative implications of environmental science is a project we see as central to any notional 'critical' physical geography. Our suggestions merely contribute to an existing landscape and discourse. For example, Bracken and Oughton (2006) argue for 'active listening' with colleagues of different epistemic persuasions as a means for encountering divergent values and framings of environmental problems (see

also Aslan *et al.* 2014). In a similar vein, Lane (2014) argues that scientists should step outside their conventional networks to embrace new norms and practices, and that scientists have a role to play in 'slowing down decision making' to enable more effective deliberation about the means and ends of environmental science. Similarly, we encourage broad exploration of how environmental science works to perform environmental framings and values, and echo calls to develop and test the normative potential for new ways of doing things through 'critical' practices.

Conclusion – from awareness to en/action

We have argued here that 'being critical' presents important and diverse opportunities for building reflexive engaged institutions of physical geography. Is this a model of integration? Perhaps, but rather than focusing on a formula of integration, we have tried to lay out some thinking to help to cultivate diverse, reflective and enactive disciplinary practices.

Physical geographers have remarkable capacity to create spaces of engagement that promote and enact critical thinking on environmental issues. Indeed, we are *already* enacting environmental problem framings, solutions and values through multiple circuits, sites and networks. Thus, being critical is less about *opting in* to a particular subset of interdisciplinary interests and more about *taking deeper responsibility* for the meaning of our practices (which may require new practices). This entails recognising (and thus expanding) the range of sites and mechanisms through which the world gets made, and thus expanding our individual and collective

capabilities to make the world differently (see Table 2). Consideration of our own perspectives and their political framing is a fundamental starting point in these deliberations. This prompts greater appreciation of the opportunities and limitations in the work done through research processes and outputs. Politics is embodied and reproduced in models and methodologies. It is legitimised through power/knowledge relationships. As a result, it assumes a range of roles in work through multiple lines of action (see Table 1), distributing environmental risks and benefits and fashioning mechanisms of governance. By cultivating a reflective and enactive disposition, we can be more attentive, strategic and effective in our efforts to support the production of fair and ecologically sustainable environmental futures. Cultivating critical practices is about making visible the invisible and exploring how steps can be taken to instigate substantive applications and outcomes.

Having said this, we acknowledge that engaging with critical enquiry and promoting new developments is not straightforward and easily accomplished (if they were we would hopefully be doing this more effectively already). There is no magic wand or prescriptive formula with which to consider how environmental science ought to be conducted in a more appropriate manner. Rather, thinking critically might begin to open up new questions about future prospects such as, where do our graduates go institutionally, geographically, and what kinds of work do they do? How are our practices as teachers and researchers – in various ways – capable of intersecting with, responding to and influencing their needs and trajectories? In the end, in addition to asking ‘what kind of environmental science for what kind of politics?’ we can also ask ‘what practices are we pursuing to enable these conversations across multiple sites and through multiple mechanisms?’ Perhaps inevitably these prospects reflect our own political engagements (advertently or otherwise). Maximising prospects for deeper engagement through a critical physical geography will require us to take steps to reconfigure our practices, recognising how we are variously framing, understanding and affecting the world, and striving to maximise the effectiveness of activities that can help us to go further.

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