This is the peer reviewed version of the following article:

Fenwick T (2014) 'Sociomateriality in medical practice and learning: Attuning to what matters', Medical Education, 48 (1), pp. 44-52, which has been published in final form at http://onlinelibrary.wiley.com/doi/10.1111/medu.12295/full.

Sociomateriality in medical practice and learning: attuning to what matters
Tara Fenwick, University of Stirling

Abstract

CONTEXT
In current debates about professional practice and education, increasing emphasis is being placed on understanding learning as ongoing participation rather than as acquiring knowledge and skills. However while this sociocultural view is important and useful, issues have emerged in studies of practice-based learning that point to certain oversights. Three issues are described here: (1) the limited attention to the importance of materiality – objects, technologies, nature etc – in questions of learning; (2) the human-centric view of practice that fails to note the *relations* among social and material forces; and (3) the conflicts between ideals of evidence-based standardized models and the sociomaterial contingencies of clinical practice.

DISCUSSION
It is argued here that a sociomaterial approach to practice and learning offers important insights for medical education. This view joins a growing field of research in the materiality of everyday life, which embraces wide-ranging theoretical families that can only be briefly mentioned in this short paper. The main premise they share is that social and material forces, culture, nature and technology, are enmeshed in everyday practice. Objects and humans act upon one another in ways that mutually transform their characteristics and activity. Examples from research in medical practice show how materials actively influence clinical practice, how learning itself is a material matter, how protocols are in fact temporary sociomaterial achievements, and how practices form unique and sometimes conflicting sociomaterial worlds, with diverse diagnostic and treatment approaches for the same thing.

CONCLUSIONS
The article concludes with implications for learning in practice. The shift is from sole emphasis on acquiring knowledge representations to learning how to participate more wisely in particular situations. Focus is on learning how to attune to minor material fluctuations and surprises, how to track one's own and other's effects on the 'intra-actions' and emerging effects, and how to improvise solutions.

INTRODUCTION

I will remember that there is art to medicine as well as science, and that warmth, sympathy, and understanding may outweigh the surgeon's knife or the chemist's drug.

Hippocrates may be misinterpreted as presenting an idealized and probabilistic medical practice, overly focused on altruistic patient-centredness and not terribly relevant for the complexities of contemporary technoscientific medicine. Yet in this excerpt the patient is not isolated as the central focus. What *is* clear is the invocation of broad *social* as well as

material forces in medical practice and knowledge per se, emotion and meaning alongside the knife and the chemical. The appeal to art and science evokes vast worlds that both rely upon creative uncertainty and improvisation as much as rational certainty and discipline. Further, Hippocrates points to interplay among these forces, the relationships among the social and material, and the implication of the physician amidst these relations. Indeed, Hippocrates clearly prescribes an ethical responsibility to the physician – 'I will remember' – as a *participant within* these broad relations.

In studies of professional practice and learning more generally, there is growing interest in understanding these sociomaterial relations of everyday work more precisely: why *matter* matters, and how to unpick the abstractions that can blind us to the micro-dynamics that influence everyday practices. Educators working from sociomaterial approaches are encouraging new practitioners to attend to these quotidian material details that stitch together their practice, knowledge and environments – not just to *attune* very closely to the connections, but also to *tinker* and improvise, to interrupt, and to seize emerging possibilities.

CURRENT ISSUES
As Mann[1] has argued, context is critical in medical practice and learning in practice. She joins a broad river of researchers who have been showing that learning cannot be considered solely in terms of individual cognitive processing. The content and process of learning changes dramatically with particular situations and patients, the tools available, technologies, social relations and other environmental dynamics. Conventional metaphors of knowledge 'acquisition' and transfer are being replaced with understandings of 'participation' and active engagement in communities. Mann accurately documents the widespread uptake in professional education of focus on 'communities of practice'[2], experiential learning and affordances in situated learning environments. She concludes that these 'sociocultural' learning perspectives are particularly fruitful for medical education.

And indeed, sociocultural orientations have been important across professional studies for interrupting fixed notions of knowledge as developed by science and then implemented by practitioners. However the community of practice approach has been critiqued not only for its conservatism, managerialism, and limited analysis of power relations in workplaces, but also for its generalized and almost romantic notions of both 'community' and practice in professional work[3,4]

Further issues are developed in more detail below. First, researchers have pressed for much more recognition of the ways that materials *actively* configure practice and knowing. Second, practical challenges facing medical practitioners including students are increasingly being understood in terms of different ontologies - different socio*material* 'worlds' being performed - not just different perspectives or meanings. Third, specific challenges are raised about the disconnection between evidence-based protocols and everyday practice, raising questions about the role of these general models in medical learning, as well as about what exactly is happening in the complexities of practice. As we see throughout this section, researchers grappling with these issues have reached for

new theories. These are broadly referred to here as sociomaterial approaches, and are explained in the subsequent section. But first, let us examine examples of current issues leading to these approaches.

Missing matter
Materials – things that matter – are often missing from accounts of learning. Materials tend to be ignored as part of the backdrop for human action, dismissed in a preoccupation with consciousness and cognition, or relegated to brute tools subordinated to human intention and design. Yet clearly in medical practice, the particular kinds of materials available and the weight of authority ascribed to them in certain settings – antibiotics and analgesics, bronchodilators and EKGs, catheters and laparoscopes, policies, databases and protocols – fundamentally shape practice as well as medical knowledge. Context may be critical, but to understand context simply as an abstract container is to miss the turmoil of relationships among these myriad nonhuman as well as human elements that shape, moment to moment, particular dynamics of context. Bleakley[5] contends that patient safety is frequently put at risk precisely through lack of attention to materiality. His examples such as a valve nearly left inside an abdominal cavity, or a patient almost falling when a gel mat slid across a frictionless table mattress in a steep tilt, show how it is the *relationships* among objects acting together with patients, health personnel, routines etc that transform one another to create risky situations. Bleakley argues for doctors learning to attune much more to micro-details of how materials *act* in practice.

Practical challenges as material performances
Among the major challenges in medical education, the problematic transition of junior doctors from medical schools to the wards and the general risks of error accompanying these transitions are a familiar discussion[6]. However, recent studies have attended more closely to how material worlds are involved in the learning of doctors undertaking transition. Kilminster et al.[7] for example have found that conventional models of learning do not explain the everyday material barriers that medical students encounter or the improvisations that they learn to work around these problems. We could say, following Orlikowski[8], that students' identities and activities are *performed* into being, in relation with the material objects and technologies that act to configure particular practices.

New technologies also pose continual practical challenges, and not only to novices. Implementation of these still tends to proceed from a rationalist acquire-and-transfer model, often through staff workshops (complete with large binders of print information) followed up with appraisals to monitor implementation in practice. Yet researchers are finding that failure to implement relies on a host of material factors that are rarely acknowledged. Allan shows how new integrated care pathways, such as for patient safety, often interfere with existing material infrastructures such as record-keeping artifacts that follow a different logic and perform a different world of practice (individualized patient records rather than a universalised system).[9] New systems literally introduce a new world of practice, producing a conflicting set of performances. Clinicians however are adept at juggling multiple performances simultaneously, and thus results the flurry of paper records that don't connect, as Allan documents.

Interprofessional practice also is continuing to present major challenges in health care: conflicting priorities and languages among clinicians; overlapping but not joined up services; mutual trust issues; and so forth. Moving beyond social and cultural interpretations of these issues, researchers have increasingly focused on material negotiations in interprofessional practice. [10] [11] They trace how instruments or texts that have particular importance for different groups of clinicians mediate and even anchor their unique approaches. They also show how different practitioners actually perform different, even conflicting, sociomaterial *worlds* with different methods, different embodied practices, and different infrastructures. These studies are now raising powerful questions about different material 'ontologies' and how practitioners learn to work within and across them, about which more will be said later.

Whence evidence-based practice?
Evidence-based practice presumes an ideal of control, of standardized protocols that can be relied upon to produce desirable results. Yet protocols have proven to be far more contingent when one traces the material details of practice than they ever appear on paper, or than most practitioners are prepared to admit[12] [13]. Indeed, standardized practices often represent sedimented patterns that not only are problematic in some settings but also stifle critical and flexible thinking. For example, Groopman[14] shows how many patterns of medical diagnostic error accrue from these sedimented patterns: availability diagnosis (selecting a solution from those most frequent in one's material reality); anchoring (framing material reality with one powerful detail that is most familiar or immediately visible); or confirmation bias (wanting material reality to fit one's preconceptions or wishful thinking).

Others like Schubert have examined the contingency and partial solutions of medical practice, showing how any protocol becomes modified by particular material limitations of bodies, instruments, other conflicting protocols, and organizational settings[15]. In her lengthy study observing diabetes care in a Dutch hospital, Mol[16] watched clinical practices taking shape and shifting, and concluded that they were 'endlessly specific and surprising'. Despite neat and systematic treatment plans and protocols, daily care must continually adjust to unruly materialities: technologies and bodies that won't behave, patients tempted to err, and all sorts of messy, smelly, bloody, frightening and tedious activities that are difficult to do. She concludes that 'Control is an illusion *even if you master the tasks'.* In much the same way, Groopman's doctors claim that, mostly, 'We are just making it up', given the limitations in available medical knowledge and the uncertainties of contingency. So if not mastery of knowledge, skill and evidence-based protocols, what then is medical practice? Clearly materials matter, but what exactly are *sociomaterial* perspectives and how are these relevant to learning?

SOCIOMATERIAL PERSPECTIVES
In fact a range of theories can be described as sociomaterial, each with distinct perspectives and purposes. In this brief article, the purpose is to provide a very general introduction to certain shared commitments and approaches across these theories. The danger of this tactic, of course, is that useful theoretical details and debates necessarily will be obscured, over-simplified, or omitted. However the advantage is in pointing to the

range of contributions and questions for medical practice and education that are opened in different regions of this new theoretical landscape. This also avoids promoting any one theory in particular as the only or the 'best' sociomaterial approach.

What all of these perspectives tend to share, first, is a *focus on materials* as dynamic, and enmeshed with human activity in everyday practices. This is what Orlikowski[8] describes as 'the constitutive entanglement of the social and material'. 'Material' refers to all the everyday stuff of our lives that is both organic and inorganic, technological and natural: flesh and blood, forms and checklists, diagnostic machines and databases, furniture and passcodes, snowstorms and dead cell zones, and so forth. 'Social' refers to symbols and meanings, desires and fears, and cultural discourses. Both material and social forces are mutually implicated in bringing forth everyday activities. This is an understanding of relationships that pushes beyond assumptions that objects and subjects *inter*-act, as though they are separate entities that develop connections. Instead, sociomaterial accounts examine what the physicist Barad[21] describes as *intra*-actions of heterogeneous elements of nature, technologies, humanity and materials of all kinds. These elements and forces penetrate one another - they act together - to bring forth what appear to be the solid, separate, immutable objects of everyday life. Things like waves or particles emerge in particular ways according to what Barad calls the 'apparatuses' that we use to observe, work with, and make meaning of everyday materials. As we observe and work with them, we create categories that define subjects and objects. These 'cuts' in matter create boundaries that define (subjects and objects, activity and phenomena) but also open new possibilities. This is a rethinking of causality as entanglements with surprising effects, not linear relations between causes and effects.

This is a second shared understanding: that all materials or, more accurately, all sociomaterial objects, are in fact *heterogeneous assemblages*. They are gatherings of *heterogeneous* natural, technical and cognitive elements. All objects embed a history of these gatherings in the negotiation of their design and accumulated uses, whether instruments, equipment, protocols, evidence etc. In examining particular practices of medicine or medical education, researchers ask how and why particular elements became assembled, why some elements become included and others excluded, and most important, how elements change as they come together, as they *intra*-act. Bleakley[5] argues that sociomaterial analyses such as actor-network theory are so obviously useful to medical education he is surprised they aren't commonly used to highlight the relationships between people and objects, and how through these, they translate each other to create new problems or possibilities.

Third, a sociomaterial perspective views all things – human, and non-human, hybrids and parts, knowledge and systems – as *effects* of connections and activity. Everything is *performed* into existence in webs of relations: 'the agents, their dimensions and what they are and do, all depend on the morphology of the relations in which they are involved'[17]. Materials are enacted, not inert; they are matter and they matter. They *act*, together with other types of things and forces, to exclude, invite, and regulate activity. This is not arguing that objects have agency: a needle does not hop into a vein by itself. But in cannulation, many things act in assemblage with the physician's hands: vein diameter and

wall composition, flow, needle size, previous cannulation sites, bacteria, patient's condition, competing ward demands etc. Any medical practice is a collective sociomaterial enactment, not a question solely of an individual's skills.

Different interests, different approaches

For those who are interested in more in-depth exploration, a full primer to these sociomaterial perspectives is available elsewhere[18]. Those that appear most frequently in contemporary research of professional practice and learning include actor-network theory and 'after-ANT' approaches, practice theory, complexity theory, new geographies, 'new materialisms', and activity theory. ANT emerges from poststructural orientations, and is more a diffuse cloud of sensibilities than a theory given its many internal contestations among key writers such as Bruno Latour[19] and Annemarie Mol. Many terms in the literature such as 'relational materiality', 'material semiotics', STS (science and technology studies), and 'sociotechnical' studies share core commitments with ANT. Its lasting influences are a networked view of reality, and a radical treatment of human and non-human elements as equal contributors to the 'networks' that continually assemble and reassemble to generate particular activities, objects and knowledge. A lengthy discussion of ANT and 'after-ANT' studies in education is available[20].

Complexity theory is quite different in orientation, another range of competing approaches emerging not from sociology but chiefly from evolutionary biology and physics (as well as cybernetics and general systems theories). Complexity theorists Karen Barad[21] and Brent Davis have become particularly influential in studies of professional education, suggesting that we examine dynamics of 'emergence', diffraction, and connectivity in practices of knowing. Turning to new human and cultural geographies, these theories examine the material spaces and places of professional practice to show how they help produce the social, but are also produced by human activity and meaning. In professional education research, geographers such as Doreen Massey, David Harvey, Nigel Thrift and Henri Lefebvre are widely cited. Yet another branch of studies that is gaining much traction in education is calling itself the 'new materialisms'.[22] [23] These often work from ideas of philosopher Gilles Deleuze such as immanence, creativity and assemblage to examine how particular social and material forces bring forth very different ways of being.

Obviously this short article cannot address the many additional perspectives relevant to a sociomaterial focus, including those promoting 'practice theory' which are increasingly important in studies of professional learning.[24] [25] Also omitted here are discussions of all these theories' limitations. Critique and rejoinders abound, as one might expect, and these critiques may be found elsewhere.[18] However, one particularly prominent perspective that has been excluded deserves some explanation: this is cultural-historical activity theory or CHAT, most associated in professional studies with Yrjö Engeström. CHAT is widely taken up in health care research, and is thoroughly developed methodologically. However, its views of the world and the nature of knowledge arguably are qualitatively different to the positions adopted by the other theory fields described here. First, while the others are essentially *post*structural and non-normative, CHAT is rooted in a

structural Marxist explanation of the relations of capitalist production and the internal contradictions of activity systems. Second, while CHAT acknowledges the importance of material artefacts that help mediate human activity systems, these are secondary to its central concern for *human* activity: the division of labour, the cultural rules and languages, and the human purposes and meanings in the system. CHAT is clearly important for medical education researchers, but given its different orientation it is being set aside for this article. Here, what is meant here by 'sociomaterial' theories are those accruing from or influenced by ANT, complexity, new geographies and new materialisms. These begin with the assumption that practice is more-than-human, and that to understand activity and learning we need to move beyond preoccupations with human meanings and human agency.

How matter *matters* in practices and protocols

Practices of knowing are specific material engagements that participate in (re)configuring the world.[21]

Close examination of health care practice as (socio)material engagement and entanglement has shown that in fact, practices form unique sociomaterial worlds. A classic study by Mol[10] examined treatment of lower-limb atherosclerosis, following its enactment in the laboratory, doctor-patient clinic, radiology, and operating theatre. She concluded that 'atherosclerosis' materialized as a very different thing in each of these practice settings. A unique assemblage of methods, discourses and instruments not only created a different world, but also produced a different *object* – a different atherosclerosis - in each setting, with different diagnostics and treatments. The practical question then is how to patch together these different worlds of knowing-in-practice that each appear to be engaging with the same object, even though they are producing a different object through the sociomaterial configurations of their own methods. Evidence-based practices are no doubt functioning in each setting, but a broader, more flexible attunement may be needed to appreciate fundamental differences and negotiate among them.

Research into the actual sociomaterial practice of standardized protocols has found that, in fact, even strict protocols are always performed in unique ways with a sort of flexible tinkering. In one study of cardiopulmonary resuscitation practice in acute care settings, Timmermans and Berg[26] found that in most of 80 cases the protocol wasn't followed as intended. Drugs not specified were introduced, strict directives were altered in cases of hopeless patients, anxious families, or available equipment. In other words so-called standards are actually interplays, always performed anew in what they called 'local universality'.

Furthermore, examining the sociomaterality of medical practice standards more broadly, Timmermans and Berg show how that a protocol is a temporary achievement.[13] Multiple trajectories come together in a moment: protocol designers, funding agencies, the different groups of involved physicians, patients' hopes and desires, organizational facilities, laboratory capabilities, drug companies, and the patients' organs' own resilience. In practice, these trajectories are 'crystallized' through continuous intra-actions in the moment of performance. In research, we need to attend holistically to the diverse agents,

human and nonhuman, that interact to produce particular crystallisations including those that are problematic. One example of this may be found in the practice of surgical checklists. Among the debates around these protocols, it has been noted that 53-70% of surgical errors occur outside the operating room[27]. To improve patient safety outcomes, these researchers have urged attention to the multidisciplinary inputs into the checklist (ward doctor, nurse, surgeon, anesthesiologist, operating assistant) and the different stages of operative care (preoperative, operative, recovery or intensive care, and postoperative). Across these stages, the researchers show the diverse material networks that should be included on the checklist: a review of imaging studies, an accounting of all necessary equipment and materials, the marking of the patient's operative side, the hand-off of postoperative instructions, and the provision of medication prescriptions to the patient at discharge.

Sociomaterial approaches to practice focus on following these microdynamic relations among nature, culture and technology. The critical assumption is that these are contingent, ongoing, always being re-enacted. The aim is not to define what is or prescribe *what should be* but to follow closely *what emerges* through processes of 'matter-ing', that is, processes by which things and possibilities are continually brought into being and into relationships. In Barad's terms, 'the world is an ongoing open process of mattering through which "mattering" itself acquires meaning and form in the realization of different agential possibilities'[28].

One example of this is in the ways that technologies are shaping new forms of medical practice. Sandelowski argues that the importance of touch in nursing practice is vanishing, along with compassionate care for patients' material bodies, with the proliferation of imaging technologies and digital representations of patient bodies[29]. Johnson[30] shows how particular technologies evoke different knowledges as well as different medical practices. She uses a sociomaterial analysis to compare US and Swedish gynecological simulators in practice, noting that these are conceived and constructed differently and for different purposes: each reflects and produces a different approach to bimanual pelvic examinations. For Johnson, these raise questions about what model validity means, about the 'intra-actions' between student doctors and simulators, as well as between simulator designers and medical practice, as well as broader issues about how the female body is being produced through the practices configured by these. The point in all of these discussions, as Orlikowski argues through her many studies of technology in professional work, is not the inherent power of technology, but the different effects and identities that become performed when people engage with technology in practice. Technologies are materials whose outcomes are not given a priori, but always are performed through interaction with humans in practice.[8] The researcher's focus needs to be on what goes on in the *relationships* of people and technologies.

But how, among these effects, do some practices and objects become stabilized and entrenched as powerful assemblages – such as standardized protocols - while others go unnoticed? Latour delineates matters of fact from matters of concern. Matters of fact are all those things that are assumed to be decided, certain and settled. Like a car that we drive without really knowing how it works, these things are 'black boxes' that are used in

practice without critical questioning about how and why they were constructed. Black boxes can be 'facts' but also practices, policies, texts and tools in everyday work. Matters of concern are issues, controversies, uncertainties. But as Latour[19] and other sociomaterialists contend[11], most things accepted as settled facts of practice are really matters of concern whose debates have been foreclosed or obscured. The sociomaterial aim is to hold open the controversies and unpick the black boxes that masquerade as matters of fact. This suggests a turn from learning as preparation and acquisition of competency to learning as attunement, response and even interruption.

IMPLICATIONS FOR PRACTICE AND LEARNING

In sociomaterial perspectives, learning and knowing are also enactments, not simply mental activity or received knowledge. Mind, after all, is a dynamic of continuous neurological connections with the myriad matter of environments. Sociomaterial perspectives shift from an individual *learning subject* to the larger *sociomaterial collective*, and 'from epistemology and representation to practical ontology and performativity', as Jensen[31] explains.

When we accept a view of the world full of agency, *doing* things, learning shifts from sole emphasis on preparing for this world by acquiring knowledge representations to participating wisely in situ. Learning issues are how to attune to minor fluctuations and surprises, how to interrupt matters that seem settled and hold open controversies for matters of concern, how to track one's own and other's effects on the emerging sociomaterial situation, or how to improvise solutions.

In her study of treatments for Alzheimer's disease, Moser[11] compares the material enactments of medical practice to the biomedical science of Alzheimer's, with its limited understanding of what is represented by its characteristic pathological changes (we do not know if neurofibrillary tangles, synapse loss, cell death, brain shrinkage and so forth are causes, consequences, or the disease itself). Citing from textbooks for clinical practice, Moser shows a tension: here the 'matter' of Alzheimer's in treatment is not represented biomedically as pathological changes in individual brains, but as attachments among a collective of human and nonhuman participants: carers, relatives, health practitioners, and environment. She goes on to explore other clinical practices, all of which are premised on a system of relationships, whether pharmaceutical (such as acetylcholinesterase-inhibitors) or interactional (such as the so-called Marte Meo communication-based treatment developed in the Netherlands). In each of these interventions, Alzheimer's disease is framed and enacted – materialized - differently. Moser's key question is not which method is best, or which enactment of Alzheimer's is the most true or valid. Instead, she is interested in how these different material enactments influence and interfere with one another, what becomes more or less visible and what becomes more or less real, and how the role of biomedicine works as *part* of the reality of clinical practice.

Perhaps of particular interest for medical educators, Moser highlights the position of the general practitioner who must mediate these competing versions and their debates, alongside the unique contingencies of the patient and the available institutional care. This

mediation is a political practice – there is no real choice in the sense of a logical and clear direction here. The physician becomes part of the enactment with each decision, and care is a process of continuous attunement and adjustment to and with the assemblage as it evolves. Mol[16] comes to a similar conclusion in her study of diabetes treatment, where 'control is illusionary and all the elements … capricious'. The main task, Mol learns, is 'attuning everything to everything else, one way or another. What to fiddle with and what to keep fixed, is rarely obvious. What you try to do, may not work out. Try something else. Keep on tinkering. Doctoring. Caring.' Groopman[14] shows that even in cardiac physiology, practices of attending closely and continuously to unexpected tiny signals emerging in the whole sociomaterial process of diagnosis and treatment can be more productive than deductive reasoning.

Learning to do medicine may then include learning the art of tinkering. Medicine can be appreciated as a set of localized sociomaterial practices, improvisations and contingent negotiations. Medical education can look more closely at what material elements most influence the ways professionals in a particular place do their work, how materials limit or enhance possibilities for practice, why particular practices become stabilized and powerful and when these blackboxes create problems. Learning, particularly workplace learning, can focus on

- attending to minor, even mundane, fluctuations and uncanny slips
- attuning to emerging ideas and action possibilities – the intra-actions of ongoing mattering processes
- noticing one's own and others' effects on what is emerging
- tinkering amidst uncertainty, and
- interrupting blackboxes of practice to hold open their controversies and disturbances.

Overall, sociomaterial perspectives help to illuminate how, in Barad's words, 'knowing is a direct material engagement, a cutting together-apart, where cuts do violence but also open up and rework the agential conditions of possibility'[32].

CONCLUSIONS

This paradox of the *cut* that defines while opening possibilities, the rational certainty that is always materially uncertain, recalls our starting point of appreciating the art in the science of medicine. Hippocrates was concerned with medical ethics and responsibility. In promoting understanding and sympathy, he was clearly arguing for the importance of relationships. Of course, subsequent debates have wondered whether training doctors to be more responsive to patient needs threatens core values of competence in biomedical science. But it might also be possible to interpret Hippocrates as appreciating both the human and the nonhuman connections of one's material practice. His invocation of art alongside science opens the importance of space for uncertainty and improvisation as well as rational protocols. There is here a call for attunement to the myriad systems at work - and practitioners' own enmeshment within these systems - when they cut open, drug, measure and catheterize bodies.

This resonates with advocates for future medical education, who emphasize attunement to sociomaterial relations in immediate local as well as broader global senses. Among the ten priorities for medical education articulated by Hodges et al.[33] are many focused on understanding one's effects in wider systems while addressing local community needs, attuning to relationships with diverse actors and environments, diversifying learning contexts and advancing inter/intraprofessional practice. Social responsibility is a major theme too in Kuper and Deon's call for a 're-democratization' of medical education that humanizes practice in a world of technoscientific and patients' high expectations[34].

The argument is not about creating or recreating dichotomies between art and science, biomedicine and patient understanding, or evidence-based practice and everyday improvisation. As Kontos[35] has shown, to pitch 'reductionist' biomedicine against 'patient-centered' empathic biosocial medicine is to create a false war and shut down richer possibilities. The current issues of medical practice and learning outlined here point instead to an interest in examining the interplay among these diverse forces, and the enactments of practice that they produce together. Sociomaterial perspectives offer a way to trace the capillaries of human/nonhuman relationships that bring forth particular realities in practice and learning, while highlighting the opportunities and entry points for change. With such a perspective, practitioners are encouraged to appreciate fully the violence of their material engagements as well as the unknown radical future possibilities that are available at every encounter.

[1] Mann KV. Theoretical perspectives in medical education: past experience and future possibilities. *Med Ed* 2011; 45: 60-68.

[2] Wenger E. *Communities of practice: Learning, meaning and identity*. Cambridge UK: Cambridge University Press, 1998.

[3] Roberts J. Limits to communities of practice. *Journal of Management Studies* 2006, 43(3):623-639.

[4] Engeström, Y. From communities of practice to mycorrhizae, in J. Hughes, N. Jewson & L. Unwin (Eds.), *Communities of practice: Critical perspectives*. London: Routledge 2007.

[5] Bleakley A. The proof is in the pudding: putting actor–network theory to work in medical education. *Med Teach* 2012; 34:462–7.

[6] Jen MH, Bottle A, Majeed A, Bell D, Aylin P. Early in-hospital mortality following trainee doctors' first day at work. *PLoS ONE* 2009, 4(9); e7103 doi:10..1371/journal.pone.0007103

[7] Kilminster S, Zukas M, Roberts T and Quinton N. Preparedness is not enough: understanding transitions as critically intensive learning periods. *Med Ed* 2011; 45: 1006-1015.

[8] Orlikowski WJ. The sociomateriality of organizational life: considering technology in management research. *Cambridge Jnl of Economics 2010*; 34: 125-141.

[9] Allan D. Understanding context for quality improvement: Artefacts, affordances and socio-material infrastructure, published online 1 November 2012 *Health (London)* DOI: 10.1177/1363459312464072

[10] Mol A. *The body multiple: ontology in medical practice*. Durham, NC: Duke University Press 2002.

[11] Moser I. Making Alzheimer's disease matter: enacting, interfering and doing politics of nature. *Geoforum* 2008; 39: 98–110.

[12] Berg M., Mol A. *Differences in medicine: unravelling practices, techniques and bodies*. Durham, NC: Duke University Press 1998.

[13] Timmermans S and Berg M. *The gold standard: the challenge of evidence-based medicine and standardization in health care*. Temple University Press: Philadelphia, PA 2003

[14] Groopman J. *How doctors think*. Houghton-Mifflin 2007.

[15] Schubert C. Making sure. A comparative micro-analysis of diagnostic instruments in medical practice. *Social Science & Medicine* 2011; 73(6): 851–857

[16] Mol A. Living with diabetes: care beyond choice and control. *The Lancet* 2009; 373 (9677): 1756 - 1757

[17] Callon M. Techno-economic network and irreversibility. In J. Law (Ed.), *A sociology of monsters: Essays on power, technology and domination* (pp. 132-65). London: Routledge, 1991.

[18] Fenwick T, Edwards R, Sawchuk, P. *Emerging approaches in educational research: tracing the sociomaterial*. London: Routledge 2011.

[19] Latour B. *Re-assembling the social: an introduction to actor-network theory*. Oxford: Oxford University Press 2005

[20] Fenwick T, Edwards R. *Actor network theory and education*. London: Routledge 2010.

[21] Barad K. *Meeting the universe half-way*. Durham, NC: Duke University Press 2007. (91)

[22] Coole D, Frost S. *New materialisms: ontology, agency, and politics*. Duke University Press 2010.

[23] Dolphjin R, van der Tuin I. *New materialism: Interviews and Biographies*. Michigan: New Humanities Press 2012.

[24] Hager P, Reich A, Lee A. *Practice, learning and change*. Springer, 2012.

[25] Gherardi S., Strati A. *Learning and knowing in practice-based studies*. Surrey: Edward Elgar 2012

[26] Timmermans S, Berg M. Standardization in action: achieving local universality through medical protocols. *Social Studies of Science* 1997; 27 (2): 273-305.

[27] de Vries EN, Prins HA, Crolla RMPH, den Outer AJ, van Andel G, van Helden SH, Schlack WS, van Putten MA, Gouma DJ, Dijkgraaf MGW, Smorenburg SM, Boermeester MA. Effect of a comprehensive surgical safety system on patient outcomes. *N Engl J Med* 2010; 363:1928-1937. DOI:10.1056/NEJMsa0911535

[28] Barad, K. Posthumanist performativity: toward an understanding of how matter comes to matter, 2003; *Signs*, 28 (3): 801-831 (817).

[29] Sandelowski M. Visible humans, vanishing bodies, and virtual nursing: complications of life, presence, place, and identity. *Adv Nurs Sci* 2002; 24(3):58–70

[30] Johnson E. Simulating medical patients and practices: bodies and the construction of valid medical simulators. *Body & Society* 2008; 14(3): 105–128

[31] Jensen C.B. *Ontologies for developing things: Making health care futures through technology*. Rotterdam, the Netherlands: Sense Publishers 2010 (7)

[32] Barad K. in Dolphjin R, van der Tuin I. New materialism: Interviews and Biographies 2012. Michigan: New Humanities press (52).

[33] Hodges BD, Albert M, Arweiler D et al. The future of medical education:a Canadian environmental scan. *Med Educ* 2011; 45:95–106

[34] Kuper A, D'Eon M. Rethinking the basis of medical knowledge. *Med Educ* 2011;45:36–43

[35] Kontos N. Biomedicine—Menace or straw man? Reexamining the biopsychosocial argument. *Acad Med* 2011; 86(4): 509-515.