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Bodily grounds of learning: Embodying professional practice in biotechnology

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<http://researchers.uq.edu.au/researcher/906>

Acknowledgements

We are very grateful to the biotechnology students who allowed us to ‘shadow’ them, and to staff who enabled access to the students, permitted us to observe their interactions with students and participated in discussions with us. We also acknowledge careful fieldwork by Ravinder Sidhu and Anna Stephens, as well as helpful comments on an earlier version of this article from Silvia Gherardi, Bill Green, Bryan Mukandi and anonymous reviewers.

Bodily grounds of learning: Embodying professional practice in biotechnology

The neglected body in education for the professions

Much of the literature on education for the professions conventionally has emphasised knowledge and skills acquisition for subsequent application in situations when they are required. Although knowledge and skills are necessary, disconnecting acquisition from application in this manner does not accord with the way in which professionals learn (Schön 1983). Moreover, skilful practice is premised upon understanding when, how, why, and in what circumstances it is appropriate to utilise specific knowledge and skills in a continually shifting world (Dall’Alba 2009, 40). Separating acquisition from application leaves unanswered the question of how decontextualised knowledge and skills can be integrated into the particularities of skilful practice, as well as how they contribute to being and becoming professionals.

Donald Schön (1983) challenged such an acquisition-application dichotomy on the basis that it promotes a notion of learning to intellectualise about practice in a manner that is separate from, rather than integrated with, practice. Such a tendency to see education as a largely intellectual endeavour has been strongly critiqued (for example, Dewey 1938; Noddings 2005). As a means of countering this tendency, various practical efforts have been made to promote ‘learning by doing’, within both formal education (for example, Negro et al. 2019; Ghilay and Ghilay 2015; Hackathorn et al. 2011) and workplace settings (Fox 2015). These efforts typically involve students or practitioners physically engaging in doing things while they learn, such as in workshops, fieldwork, laboratory experiments, simulations, practicums and internships. In many of these efforts, however, little attention has been paid to the manner in which engaging in ‘doing’ brings about the desired learning. Occurrence of this learning is largely taken for granted (cf. Dewey 1938).

More particularly, the way in which the body is implicated in learning has conventionally received scant attention (with some exceptions, such as Bresler 2004; O'Loughlin 2006). In a similar vein to regarding education as primarily an intellectual endeavour, overlooking the body in this manner is a legacy of a Cartesian rupture of mind from body in Western thought traditions. As Edward Casey notes:

Human embodiment was among the first victims of the Cartesian revolution in philosophy. This embodiment ... had no place to go: still worse, no place of its own.

But like any good ghost, it has returned to haunt its exorcizers. (1998, 207)

In line with a mind-body rupture, in much of the literature on scientific experimentation 'the body and its senses are regarded unreliable in the production of objective data' (Bischur 2011, 408), which is often also evident in education within the natural sciences. Similarly, as Elspeth Probyn (2004) pointed out, in some educational literature, including some feminist literature, there has been a tendency to 'shut out' affect and the body, typically through the use of 'theory' or abstraction.

Rather than shy away from the spectre of embodiment, over recent years some research seeks to reclaim the body and embodiment in a range of human endeavours (for example, Allen-Collinson and Owton 2015; Gonzalez Arnal, Jagger and Lennon 2012; Green and Hopwood 2015), including in educational settings (for example, Leigh, 2019; Mulchay 2015; Reid and Mitchell 2015; Todd 2016). In highlighting the significance of the body in multifaceted relationships between societies and formal education, Chris Shilling (2010) distinguishes body pedagogics prevalent within society, such as ideals about the body evident in health promotion, workplaces and consumer culture, from body pedagogies apparent in curricula and schools. In other words, he distinguishes between 'societal body pedagogics and educational body pedagogies' (164). In school-based research, the relationship between the two has been of particular interest in the area of health and physical education (for example, McCuaig and Hay 2013), especially in relation to the notion of healthy bodies.

Across the disciplines in higher education, in student placements, internships or other forms of experiential learning that occur in workplaces, the distinction between the two may be somewhat less clear, as the workplace and site of formal education are one and the same.

In efforts to deepen the notion of experiential learning, some studies sought deliberately to engage the body in learning in a range of disciplines, such as through gestures, movement, fieldwork, simulation or roleplay (for example, Ivinson 2012; Swartz 2012; Wagner and Shajhahan 2015). Some of these studies draw upon cognitive science and/or neuroscience (see Skulmowski and Rey [2018] for examples), while the learning effects have varied. Other studies highlight the importance of embodied experience, including sense perceptions, the intellect and emotions, for learning in fields as diverse as cultural studies, dance, geography, mathematics, medicine, nursing, teacher education and theatre (for example, Barnacle 2009; Gilbert 2013; Hopwood et al. 2016; Kelly et al. 2019; Pierce & Widen 2016; Reid and Mitchell 2015; Standal and Engelsrud 2013), as well as harnessing embodiment for re-thinking experiences of gender, class, race, sexuality and dis/ability (Cravey and Petit 2012; de Freitas 2016; Sutherland 2013).

Joseph Pierce and Holly Widen caution, however, that teaching in ways which draw upon embodied experiences ‘can elicit complex reactions from students that do not necessarily or straightforwardly lead to greater attention to the learning process’ (2016, 53). As Sharon Todd points out, bodily ‘sensibility is precisely that which cannot be contained, directed or enforced by tightly defined procedures and institutional arrangements’ which ‘challenges the assumption that the “right” kind of teaching will produce the “right” learning outcomes’ (2016, 409). This challenge also applies when students’ embodied experiences are overlooked in teaching. It follows, then, that learners can learn different things—not simply less or more—from the same learning situations.

Studies such as those cited above turn attention to learning through the body, contributing to addressing an overemphasis on the ‘mind’ or intellect in learning at the

expense of embodied knowing. Importantly, this shift in emphasis brings with it a concern for the situatedness of learning in context, which cannot adequately be accounted for by a disembodied mind or 'doing' things. Nonetheless, a continuing area of neglect relates to the significance of the body in learning to enter the professions, especially outside teaching and teacher education.

In this article, we target this neglected area of research. We build upon earlier work which recognises that learning to engage in our various activities and endeavours implicates the body in continuing interaction with others and things in our world. In particular, we extend previous research on the relationality of body subject and world, while turning attention to learning for the professions, although we acknowledge that our analyses may also have broader relevance. Our purpose is to explore *what is entailed in learning to embody skilful performance by aspiring professionals* in the recently prominent, highly technologised field of biotechnology. The notion of skilful performance we use here refers to complex performance that requires substantial know-how. We also recognise that skilfulness varies, including when individuals or collectives are 'equally qualified' or perform the 'same' work. The focus we adopt on embodying skilful performance allows us to critically examine the notion of 'learning by doing' as students engage in the process of learning. More specifically, we explore learning with and through the body that occurs while students endeavour to enact the practice of biotechnology. Our primary interest, then, is the significance of the body in, and for, education for the professions.

In this study, we conduct philosophical-empirical inquiry (Green and Hopwood 2015; Kemmis and Mutton 2012; Santoro 2015) in which we interweave philosophically-informed theorising with analysis of accounts from our empirical research with biotechnology students. As Doris Santoro points out, such philosophically informed theorising serves as a 'sensitizing instrument' for empirical analysis (2015, 172). In particular, our research is underpinned by Maurice Merleau-Ponty's ([1945] 1962) notion of the 'lived body,' which highlights the body

continually engaged in the world. Despite some limitations, the concept of the lived body provides a rich resource for exploring the ‘bodily grounds’ (Sheets-Johnstone 2015) of learning to enact practice, as students attempt to become professionals. Given our interest in being and becoming professionals, we also draw upon Martin Heidegger’s argument that our modes of knowing, such as biotechnology, visual arts and physiotherapy are ways of being in the world ([1927] 1962, 408). In other words, they are our way of relating to others and things in practice worlds, such as the world of biotechnology, architecture or occupational therapy. This means that becoming professionals includes not only acquiring knowledge and skills, but learning ways of teaching, engineering or nursing that have relevance for the time and place in which they are embedded. These ways of being professionals are never entirely ‘fixed’ or final, but always in a process of becoming, even among experienced professionals. The broader framing for our study is derived from this notion of ways of being, drawn from Heidegger, while Merleau-Ponty’s lived body furnishes the means by which these ways of being become embodied in learning to be professionals.

In exploring learning among aspiring professionals, with their agreement we ‘shadowed’ university students in classrooms and laboratories as they completed the final year of a biotechnology degree program. We contextualised this learning in our empirical setting through discussions with key teaching staff and course documents.

The contributions of the present inquiry are twofold. We outline a *theoretical account* of what is entailed in learning to embody skilful performance by those aspiring to become professionals. In doing so, we also illustrate and enrich this theoretical account through *empirical inquiry* into students learning to embody the practice of biotechnology in their final year of a higher education degree program. Extending and deepening our understanding of aspiring professionals learning to embody skilful performance has the potential to provide insights into educational processes, pedagogies and technologies for enriching skilful performance and nurturing well-being.

Below we describe the way in which we theorise and conceptualise learning with and through the lived body in becoming professionals. We then describe our methodological approach and the empirical setting for the study. Against this background, we elaborate three distinctions that assist us in exploring the bodily grounds of learning to become professionals. The distinctions we feature are: epistemological and ontological dimensions of learning (Dall’Alba 2009) based on the notion of ways of being, drawn from Heidegger; Merleau-Ponty’s ([1945] 1962) characterisation of ‘the body I am’ and ‘the body I have;’ and his ‘habitual’ and ‘expressive’ body. While these distinctions have been discussed elsewhere in relation to other topics, here we bring them together for the purpose of elucidating embodied learning among aspiring professionals in biotechnology. Finally, we point to some implications that can inform educating for the professions.

Theorising learning through the body in becoming professionals

Although we draw attention to learning with and through the body in this article, this is not to be misunderstood as implying a focus on individual, physical bodies, distinct from the sociomaterial practice world(s) they inhabit. As we note above, embodiment was an early casualty of a Cartesian tradition, which has had substantial flow-on effects into formal education. This is evident in the continuing prevalence of lecture theatres and online ‘talking heads’ in higher education, with attention to ‘educated minds,’ while bodies (of both students and teachers) in their worldly interactions are often overlooked. Although lectures can be inspiring educational experiences, the perspective on education that historically led to their prevalence has emphasised intellectual development at the expense of other forms, such as situationally appropriate ethical action or emotional well-being.

For Merleau-Ponty, the body is not merely a material object among other objects, nor is it limited to interconnected physiological systems; rather, it is the perceiving, feeling, motile body as we *live* it, continually directed toward the world. He argued that I have ‘not only an experience of my body, but an experience of my body-in-the-world’ (Merleau-Ponty

[1945] 1962, 141). As noted above, several more recent studies highlight the importance of embodied experience for learning in a varied range of empirical settings, confirming the significance of this ‘experience of my body-in-the-world.’ Giovanna Colombetti points out that this lived body is ‘the condition of possibility for our experience’ of the world (2016, 232).

Merleau-Ponty noted, however, that this body-world relation is not straightforward, but necessarily incorporates ambiguity:

When I press my two hands together, it is not a matter of two sensations felt together as one perceives two objects placed side by side, but of an ambiguous set-up in which both hands can alternate the roles of ‘touching’ and ‘being touched’. ([1945] 1962, 93)

In other words, ‘I apprehend my body as a subject-object, as capable of “seeing” and “suffering”’ (95). Attending to this ambiguity provides a means of exploring some of the texture and complexity of engaging with our world as body subjects.

It is this engagement with, and directedness to, the world that enables us to learn, so meaningful learning is not limited to the intellect and/or to ‘doing’ things. Instead, learning new activities and practices involves a ‘rearrangement and renewal’ of our lived body (Merleau-Ponty, [1945] 1962, 142). Merleau-Ponty described a dialectical relationship in which the body-in-the-world is shaped by, and shapes, the world-in-the-body. This dialectical relationship is a further exemplification of ambiguity in our relation with world. For instance, students learning procedures and protocols in biotechnology are bodily shaped by this world of biotechnology toward fluent performance in which they, themselves, come to shape what biotechnology can be in the present and become into the future.

The world of biotechnology is not self-contained, but overlaps with other practice worlds, such as the world of higher education that provides preparation for biotechnology professionals (for elaboration on ‘the nexus of practices,’ see Hui, Schatzki and Shove

[2016]). These overlapping practice worlds are embedded in a broader significance whole (Heidegger, [1927] 1962, 93), which gives meaning and purpose to these endeavours. From the later part of the 20th and into the 21st century, new scientific advances, especially in molecular biology, gave rise to rapid developments in biotechnology, including in areas such as genomics, biofuels and newer forms of pharmaceutical drugs. These advances have been accompanied by discourses that tend to promise unmitigated benefits, attracting stakeholder investments, prompting government policy and regulations, as well as provoking consumer demands. The gains to date typically have been more modest than the claims and are associated with complex social or ethical issues, such as genetic testing for identifying disease risk (for further examples, see Holloway [2011]). The activities of biotechnology students and professionals are afforded meaning and significance within the context of opportunities and constraints surrounding these efforts to harness biological technologies for purposes such as developing genetic or pharmaceutical treatments, providing agricultural products and targeting environmental issues.

Methodology and empirical setting for exploring embodied learning

The final year undergraduate students we followed in our research were busy in laboratories embedded within the broader world of biotechnology. Throughout this final year, the students worked within teams of scientists on research projects located in various biotechnology organisations or university laboratories. In common with many other forms of student fieldwork and placements, this introduced challenges and opportunities as the students were expected to engage in ongoing practice and projects, while not yet commanding the skilfulness required to do so. This discrepancy was expected to initiate learning, which calls into question both an overemphasis on the intellect at the expense of embodied learning and also the notion that what has been previously learnt can simply be applied in new contexts.

In addition to their projects, the students completed courses on commercialisation and intellectual property, which were intended to introduce them to harnessing biological

technologies for commercial and industrial purposes. The coordinator of the biotechnology degree explained they were preparing students for ‘*meeting a demand*’ in ‘*getting the products of science out to the community.*’ He described the focus of the degree, as follows: ‘*It’s core science with the icing on the cake being the introduction to biotech and the commercialisation of biotech products,*’ such as pharmaceutical drugs, agricultural products and so on. He went on to explain that employers want graduates who are strong in science, as well as:

attuned to the special needs of industry in terms of the level of documentation of [product] invention that’s required, knowledge of protection of intellectual property, the need for confidentiality, and the more stringent requirements for quality assurance and quality control in the industry.

He summed up by saying, ‘*the top biotechnologist will be a good scientist, but also from the very beginning of the research project will be aware of the commercial imperatives.*’

Similarly, the final year coordinator explained the program sought to provide a ‘*bridge between the good science and the good business.*’ The students we followed were striving to become scientists within this world of biotechnology.

Given our interest in learning with and through the lived body in becoming professionals, a challenge in our research is to portray discursively what and how the students were bodily performing. We have attempted to do this by empirically exploring various textures of the students’ engagement, such as the ways they relied upon sensory perception and motility in responding to the tasks at hand, as well as ambivalences, ambiguities and emotions they experienced as they were learning. In some sense, the challenge we experienced parallels demands made of the students in bodily enacting what they were learning, including from lectures, seminars, laboratory work, journal articles and their interactions with more experienced scientists. These challenges relate to the question of how

professional practice can be meaningfully portrayed or ‘represented’ (see Green [2009] for exploration of this issue), including in educational settings.

In order to explore how final year undergraduate students learned to embody the practice of biotechnology, we contacted them as a cohort by email and during lectures at the beginning of the academic year, explaining our research and calling for volunteers. During a year of heavy commitments for them, our research focus necessitated we work closely with student participants across the academic year. Nine students agreed to participate in individual, audio-recorded conversations early and late in the year, as well as observations and spontaneous discussions at several points during the year, while they worked on year-long biotechnology projects as part of their degree program. The projects varied in topic and focus, such as targeting disease in specific plant crops, a bioinformatics project for assembling genetic material, and impacts of particular treatments on human stem cells.

One of two principal investigators in our team led the audio-recorded conversations with students, with assistance from two research assistants, one of whom contributed to each of these conversations. During some of our observations, we video-recorded students as they worked on their projects, including while interacting with their project supervisors. We also observed some class sessions, such as an introduction to the final year, and classes during a course on commercialisation and intellectual property. In addition, we audio-recorded discussions with the coordinator of the biotechnology program and with the final year coordinator, as well as obtaining documents about the program.

The course documents, observations of class sessions and audio-recorded conversations with senior teaching staff provided us with the broad context—both within and following the program—for the student learning experiences we documented in our research. Against the background of this initial contextualisation in our empirical setting, our analysis took the form of a dialectic that moved back and forth between philosophically-informed theorising and the varied empirical materials we had obtained, with theory and empiry

informing each other. We worked across our empirical materials throughout the analysis, as together they provided us with a fuller appreciation of what is entailed in learning to embody the practice of biotechnology. For instance, while interrogating the documented observations and visually rich video recordings of students engaged in practice, we were able to examine the students' own descriptions and reflections about their practice during conversational interviews. The philosophical-empirical dialectic in which we engaged is evident in the sections that follow, wherein we interweave philosophically-informed theorising with our analysis of empirical material.

Learning through the body in biotechnology

Below we describe the outcomes of our analysis in which we draw on the various sources of empirical material, interweaving them with theorising, as a means of exploring the texture of what is entailed in learning to embody skilful performance by aspiring professionals. In particular, we employ interrelated distinctions that assist us in depicting the bodily grounds of learning to become professionals. These distinctions are *both* theoretical *and* empirically based; we draw upon theoretical distinctions that manifest in our empirical material. As we elaborate in what follows, the distinctions are between epistemological and ontological dimensions of learning, the 'body I am'/'body I have' and the expressive/habitual body. We consider these distinctions to be especially useful in illuminating what is entailed in learning to embody skilful performance by aspiring professionals, although we do not claim they exhaustively capture this learning.

The dialectics highlighted by each of the three distinctions demonstrate some aspects of the means by which learning occurs through directedness to our world. Each distinction, moreover, points to ambiguities in this relation with world. It is important to note, then, that each of the distinctions is not intended to identify a dichotomy. Instead, they reveal interrelated aspects of embodied learning, which are distinguishable only for analytical purposes, as we demonstrate below. Within each of the three distinctions (and sections) that

follows, we have underlined the main features of learning with, and through, the body that emerged in our analysis.

Epistemological with ontological dimensions of learning

We begin our analysis of learning to embody practice with a distinction between epistemological and ontological dimensions of learning (Dall'Alba 2009). This distinction serves to counter an overemphasis on the 'mind' or intellect in learning, by also highlighting the embodied being in the world that accompanies intellectual development. In pointing out that modes of knowing are ways of being in the world, Heidegger ([1927] 1962) highlighted an inevitable interrelationship between knowing (or epistemology) and being (ontology). Iain Thomson explains this relationship, as follows:

Our very 'being-in-the-world' is shaped by the knowledge we pursue, uncover, and embody. [There is] a troubling sense in which it seems that we cannot help practicing what we know, since we are 'always already' implicitly shaped by our guiding metaphysical presuppositions. (2001, 250)

This interrelationship between knowing and being has particular relevance for learning in educational and workplace settings, which we explore below.

As the students in our study strived to enter the world of biotechnology, over time they were required to learn to embody its routines and practices. As well as an intellectual endeavour or skills acquisition, this process entails learning to be scientists in biotechnology, with the commitment and personal investment that this demands. Learning to enact the practice of biotechnology with and through the lived body constitutes the body subject as (aspiring) scientist in relation to this world of biotechnology (see also Dall'Alba, Sandberg, and Sidhu [2018]). As Marjorie O'Loughlin noted, 'our bodies are nothing less than our characteristic way of being in the world' (2006, 14).

In our study, a student we call Paul was involved in developing a new computer program to assemble longer sequences of genetic material than a standard method produced.

In his view, this required working out both ‘*the logical steps required*’ and ‘*you have to work out a way to get the [programming] language to say*’ the steps you need it to perform (final conversation). On several occasions, the new program he tried included errors or ‘bugs,’ so did not function well. Paul carefully analysed many rows of extended computer code he had devised, to determine whether this code performed the necessary steps in a complex sequence. However, he sometimes had difficulty identifying or locating the ‘bugs.’ When the students encountered difficulties they were unable to resolve, they typically relied upon the more extensive experience of their supervisors or other scientists. A key way in which students learned to move forward with their projects was through taking up others’ ways of being and making them their own. This involved appropriating other ways of knowing, acting and being, rather than simply imitating them. Paul pointed out he had learned something important from his supervisor’s way of practising biotechnology:

She always wanted to know why. That is where a lot of what I learnt came from. I think I’m coming into the conversations having thought things through more.... I think about the justification for doing stuff now as well. She’s got a huge influence on that.
(final conversation)

So, this student was learning not only to enact gene sequencing and computer programming for genetics projects, but also learning how to be a biotechnology scientist, including justifying procedures, collaborating with others and sharing knowledge; all central to the practice of science in our globally interconnected world. As O’Loughlin notes, ‘body subjects, by virtue of their involvement with the social world, develop *culturally typical* ways of being and doing’ (2006, 14).

In contrast, when the students considered the experienced scientists did not sufficiently support their learning, the experience was less positive. Peter described working on a project in a different laboratory:

You are completely on your own. They'll be like, 'Do this.' And you have to try and figure out a way to do it.... They think it's just intuitive and you're like, 'No, I need to be taught these things.' A few accidents were coming out of that lab just because people weren't shown the techniques properly. (final conversation)

Based on the students' accounts and our observations, supervisors varied in the extent to which they instructed students, as well as in actively engaging students in understanding the rationale for the tasks. Even if the students learned the 'same' knowledge and skills, they may learn different ways of embodying what it means to become biotechnology scientists.

Without the necessary instruction and guidance, they may learn to carry out specific techniques or procedures, while learning to be a biotechnology scientist in a limited—indeed, constraining—way. This is because learning incorporates not only *what we know or can do* (an epistemological dimension), but also *how we are learning to be* (an ontological dimension) (Dall'Alba 2009). In other words, learning extends beyond both the intellect and 'doing' to encompass who we are becoming in how we relate to our world. This overlapping of knowing and being indicates their inherent interrelatedness, as well as ambiguity in the process of learning.

As Peter's comment indicates, this is not to suggest the students unquestioningly took up others' ways of being. Rania was acutely aware of resisting her supervisor's efforts to shape her into what she regarded as his ideal:

It's kind of like having parents. I came all the way here out of that.... And just trying not to kind of turn into, I don't know ... his ideal or something.... Also that he wants me to present a lot ... because he thinks I'm a bit shy. So yeah, I guess he wants me to [be] a bit more outspoken or anything. I'm not really into that. (initial conversation)

The tension associated with this resistance can contribute to a sense of having a bodily way of being that does not 'fit' well with what is valued in the specific context. Moreover, this tension can occur for both novices and experienced professionals in their efforts to be valued

participants who contribute to practice worlds. As O’Loughlin points out, in contemporary neoliberal organisations, ‘individuals are expected to wholeheartedly embrace change not only in what they *do* but also in what they take themselves to *be*’ (2006, 100). She argues that an expectation of continual growth and constant change carries a risk that ‘the fact of workers’ embodiment disappears’ from view (101). A similar risk occurs for students when they are expected to fit particular moulds that take no account of who or how they aspire to be, including as professionals (see also Barnacle and Dall’Alba [2017]). At the same time, it is also necessary that students learn to meet particular requirements, modes of practice and standards in entering practice worlds. This is central to the purpose of these professional education programs. There is a delicate balance, however, between coercion and education.

Further complexities can also occur when bodily ways of being do not ‘fit’ well with their context. In challenging Cartesian dualism, Merleau-Ponty emphasises that our continuing directedness to our world is ‘not a matter of “I think that” but of “I can”’ ([1945] 1962, 137), in which our bodily being towards the material, sociocultural world is foregrounded (138; Heidegger, [1927] 1962, 87). In a manner that also highlights the world-in-the-body, Iris Young cautions, however, that the experience of ‘I can’ may be less unequivocal than the version Merleau-Ponty posits as ‘an open and unbroken directedness upon the world in action’ (1990, 148). She argues, for instance, that in male-dominated societies, often ‘feminine bodily existence is an inhibited intentionality, which simultaneously reaches toward a projected end with an “I can” and withholds its full bodily commitment to that end in a self-imposed “I cannot”’ (148-149). This ambiguous relation to one’s own capacities is characterised by conflicted emotions that may impact achievements.

Although we exercise caution due to the relatively small number of students who participated in our research, we observed female students, but not male students, questioning their own capacities in an ‘I cannot.’ Peter attributed slow progress to the ‘*luck of the draw*’ in his project, as well as later in the year wondering whether he wanted to continue in

biotechnology. He did not appear to consider whether his own capacities were suited to this field of endeavour. On the other hand, some of the female students, at times, questioned their own capacities in the form of an ‘I cannot,’ as well as acknowledging their achievements in an ‘I can.’ For instance, Emily was initially ambivalent about proceeding to the final year after her grade on an examination ‘*wasn’t that good*’: ‘*I don’t know whether or not I’m really good at this, I’m starting to question that*’ (initial conversation). Following a positive experience working on a supervised project during the summer preceding her final year, she decided to continue:

I keep on telling myself I’m maybe not that brilliant ... but I know I’m going to work really hard ... because you see all these amazing people, who really know well what they’re doing. So you want to be as good as them ... to provide something for the [work]group. (initial conversation)

By the end of the final year, she attributed some of her success in laboratory work to good fortune: ‘*I’m fortunate that the one time I did it, it works well*’ (final conversation). She also spoke confidently that ‘*If you throw me anywhere [in biotech labs], I will know a bit what to do and learn from there.*’ As an international student, it is possible Rania’s perceived ‘shyness’ may be related to being outside the more familiar context of her home country and mother tongue. In line with Young’s observations, the extent to which Rania feels comfortable to move and breathe freely within the spaces she currently finds herself can be expected to influence the way she acts in those settings. As well, what is considered shy, accomplished or exaggerated behaviour can vary across social and cultural settings (see, for example, Colombetti [2016]). The ambiguity and dialectic of the body-in-the-world with the world-in-the-body is at play.

Similar to Young, it is not our intention to imply an essentialist notion of gendered, age-related, sexed, racialised, dis/abled or classed existence. On the contrary, Young’s observation about, and qualification on, Merleau-Ponty’s ‘I can’—with some corroboration

in our study—calls attention to ways in which opportunities, constraints, hesitancies and accomplishments in bodily performance can be influenced by the contexts in which they occur. While participants may exercise some degree of resistance or subversion, developing culturally typical ways of being and doing occurs within already established sociomaterial worlds that vary in their openness to diverse others and to change. Being towards the world necessarily involves, then, living out opportunities and constraints in relation to the unfolding practice worlds we inhabit; the dialectic of the body-in-the-world with the world-in-the-body.

The ‘body I am’ and the ‘body I have’

In the context of an inevitable interrelationship between epistemological and ontological dimensions of learning, we now turn to elaborating further the manner in which ways of being become embodied during transitioning into practice worlds. In particular, we explore some ambiguities of the body-world relation in which Merleau-Ponty describes the body as ‘subject-object’ in our experience of it. More specifically, we explore the students’ experience of both ‘having’ and ‘being’ a body, directed to the—as yet, still unfamiliar—world of biotechnology.

In exploring how students learn to embody the practice of biotechnology, we examine ways in which they employ the perceiving, moving, feeling body—with varying degrees of success—in beginning to perform tasks and activities that are integral to this practice world. At the same time, Merleau-Ponty distinguishes this ‘body I have’ from the social, cultural ‘body I am,’ although he makes clear the two are ‘not disjoint but inherently related’ (Sheets-Johnstone 2015, 26). As Merleau-Ponty explains:

Whether it is a question of another’s body or my own, I have no means of knowing the human body other than that of living it, which means taking up on my own account the drama which is being played out in it, and losing myself in it. I am my body, at least wholly to the extent that I possess experience, and yet at the same time

my body is as it were a ‘natural’ subject, a provisional sketch of my total being.

([1945] 1962, 198)

The biotechnology students pointed to this sense of ‘losing oneself in the drama,’ which counters the common myth perpetrated among natural scientists that objectivity and detachment rule in the laboratory, while emotions and subjectivity are left outside (for further analysis, see Harding [2015]). In contrast to this myth, the students argued that being scientists in biotechnology calls for passion and perseverance. As Emily pointed out:

Everyone is so excited every time they got new data and you can’t help to be excited about it.... Other than the academic stuff ... you have to have a lot of passion to what you’re doing. You can see it in every member of the lab. (final conversation)

The students employed the ‘body I have’ in learning to carry out the work of a scientist, while also committing the ‘body I am’ or, in other words, the emergent scientist-self, to being part of the practice world of biotechnology:

You try to be involved and, you know, be a scientist, let’s just say. And really immerse yourself in the [biotech] project and try, like, to understand it, you know, in a critical way. (Emily, initial conversation)

The distinction between ‘the body I am’ and ‘the body I have’ has particular relevance for learning by aspiring professionals, as they attempt to embody features of practice that are new and unfamiliar to them. However, this distinction tends to be overlooked when focusing primarily on either intellectual development or unclear notions of learning by doing.

The students in our study recognised the ‘body I have’ can fall short of the ‘body I am’ striving to be. As Carol Wolkowitz points out:

In different contexts we feel ourselves as fully embodied subjects, in others we become more conscious of having a body with which we do not fully identify or which confronts us with its Otherness. (2006, 16)

Although they wore white coats similar to others in the laboratories, the biotechnology students were aware they were not (like) experienced scientists. They had some basic laboratory skills, but had not yet mastered many of the specialised techniques or equipment, nor did they initially know the approach or procedures for addressing their research questions. Even when they otherwise had positive relationships with project supervisors, the students' relative inexperience could leave them with a feeling of falling short:

It's really disheartening the first time you submit an assessment item to her or, like, do a presentation in front of her, and she's got this huge list of things to fix.... [You] leave the conversation and you've no idea why you did anything, now! (final conversation)

The complexities of the pedagogical relationship demonstrate that 'the tension between the body which is mine (that which I am?) and that which I am for others, presents particular challenges for education' (O'Loughlin 2006, 3).

During the projects, especially in the early phases, it was not unusual that students made mistakes or experienced failure. At times, an error they made during an already tight schedule meant they had to repeat procedures or whole experiments that had taken hours, days or weeks of work. They were usually aware of the costs of these mistakes to themselves, the time of the experienced scientists who had helped them, as well as the research group's budget. Once again, the 'body I have' fell short of the 'body I am' aspiring to be. Even when their techniques and procedures were not at fault, they also experienced the unpredictability and contingency of research in which results were not as expected. It was often through these experiences that students learned about the processes, and inevitable failure, inherent to scientific research. As Diana noted, '*Not everything can be successful, there's always failures in everything*' (final conversation).

Over time, the students learned how to utilise the 'body I have' in employing the necessary techniques and protocols, which were heavily reliant upon performing bodily

through sensory perception. The students carefully observed visual cues or readings from equipment to monitor what was occurring, such as whether or not a procedure achieved an expected result. For instance, they may be alert to colour change, growth in cells or plants, moisture levels, formation of crystals and so on. In order to bodily perform their laboratory experiments, the students refined their tactile sense of how to manipulate tools and equipment appropriately for the purpose. They initially handled these tools and equipment more gingerly, slowly and hesitantly than more experienced scientists. Some students pointed to the clumsiness they felt when learning to use new techniques or equipment, indicating an ambiguous experience of the body as ‘intimately alien, strangely mine’ (Zaner 1981, 54, cited in Burwood 2012, 134). With experience over time, they developed an enhanced tactile sensitivity: *‘The first time may be like “Oh my gosh, did I put that thing in there!?” ... Then after a few attempts, “Yeah, I’m good at this”* (Emily, initial conversation). More successfully negotiating the ‘body I have’ was tied to a sense of accomplishment towards the ‘body I am’ striving to become.

The improvement gained and sense of achievement were not simply due to repetition of practised techniques, but relied upon heightened sensory perception, dexterity and motility that often occurred following assistance or instruction from more experienced scientists, including someone who *‘helps me work out where I went wrong’* (Rania, observation 1). Through this guidance, the students adjusted their performance in tune with the tasks at hand, thereby developing ‘culturally typical ways of being and doing.’

While the students honed their sensory perception and motility, they progressively performed tasks with fluency and rhythm. As they learned to perform with greater skilfulness, this fluency and rhythm were visible, especially over time during the year-long projects. The students’ heightened perception and motility enabled them to respond better to what was occurring, as it unfolded. Developing such ‘attuned responsiveness’ (Dall’Alba 2009, 68) is a feature of skilful performance in becoming professionals. Attunement to the

world through bodily perception, motility and emotion shapes the body as it performs—both individually and in concert with others—in sociomaterial practice worlds. This rearrangement and renewal of the lived body signals a dialectical, ambiguous relationship involving the body-in-the-world and the world-in-the-body.

Habitual with expressive body

Not surprisingly, the students we followed differed noticeably from the experienced scientists in the habitualised practice they were able to draw upon in employing techniques, trouble shooting, and moving projects forward. As evident above, in striving to become skilful practitioners in biotechnology, in general the students moved toward greater harmony between their current skilfulness and what they sought to achieve. We now explore an additional distinction that casts further light on the means by which they were able to do so.

Informing this exploration is Merleau-Ponty's proposal that the lived body comprises two dialectically related layers, habitual and expressive layers ([1945] 1962, 82). The *habitual layer* relies upon the past, in the sense that the body develops ways of performing which become habitualised over time. Through performing, the body appropriates and habitualises specific perceptions, emotions and movements making up the performance. As Monica Langer notes, through these appropriations, the habit body 'draws together a comprehensive past which it puts at the disposal of each new present, thereby already laying down the general form of a future it anticipates' (1989, 32). The habitualised practice scientists build from experience—individually and collectively—is at their disposal in each new situation they encounter. This habit body *projects* a general structure for performing into their future practice. Importantly, 'habit has its abode neither in thought nor in the objective body, but in the body as mediator of a world' (Merleau-Ponty, [1945] 1962, 145). In other words, habit is formed through the body's embeddedness in, and directedness to, a

sociomaterial world. This relationality is also evident in the expressive body, as we explain in what follows.

Against the background of habitualised experience, the scientists constantly *adjust* their performing to the particularities in each new situation. These frequent adjustments through bodily sensing and responding to particularities in an unfolding situation signify the *expressive layer* of the lived body (which Silvia Stoller [2010] argues has similarities with Judith Butler's concept of 'performativity' through the reliance on a shared notion of relationality). In this ongoing sensing and responding, the body does not yet have a clear sense of how to perform in this particular situation, but tries to grasp the situation by making it more determinate. The adjustments being made are appropriated by the lived body, in turn, thus perpetually altering and refining the habitual layer of the body in a dialectical relationship. The habit body then projects this refined way of performing into the next present in which the expressive body adjusts to the specific situation at hand, with these adjustments appropriated by the lived body, and so on. Adjustments and habits do not always lead to improvements in practice, however, which is sometimes overlooked when learning by doing is promoted. Instead, they can reinforce poor practice, especially where there is limited commitment to high quality performance or when beneficial teaching is not readily available.

The habitual/expressive distinction points to an intractable challenge for novices aspiring to enter practice worlds. While they have experience of using their bodies to engage in varied tasks, enabling them to learn new skills and practices, they attempt to respond expressively to new situations, based upon a relatively 'thin' layer of the habit body. Moreover, the habitualisation of practice by experienced scientists means much of this practice is taken for granted and, therefore, largely unnoticed by them. This poses difficulties for newcomers in discerning or inferring what they do not yet understand or embody, which may leave them with '*no idea why you did anything, now!*' Conversely, the inexperienced habit body can also present challenges for teaching, when novices do not recognise what

they, as yet, are unable to perform. Given their inexperience, the process in which expressive adjustments alter or enrich the habit body is likely to be especially active for novices, even when adjustments may not be advantageous. This highly active phase explains the more noticeable shifts in enacting biotechnology among students in our study, when compared with the greater surety of perception and fluency of movement which the experienced scientists had built up over a prolonged period.

Underlying observable shifts over time in the practice of the biotechnology students, they demonstrated expressivity through alterations they made as their projects proceeded or in response to contingencies that arose. For instance, Emily was working on a project targeting disease in an agricultural crop. The project sought to identify and map a gene that was conferring resistance to a pathogen attacking this crop, with potentially important implications for commercialisation. Some months before, an international consortium had made available a draft genome for the plant in question. This draft genome provided the starting point for Emily's project, but she and experienced scientists with whom she worked did not know which gene conferred the resistance or the mechanism by which it did so:

It's basically identifying the resistant gene and then from there it will help so much to understand, like, what are the pathways involved in that resistance ... and we use like a lot of bioinformatics tools ... and then that actually helps you to narrow down the resistance across the genome. (final conversation)

Given the genome was in draft form, it was periodically updated by the consortium. Emily's project involved accessing changes to the draft genome as these became available, drawing on bioinformatics data provided by a neighbouring laboratory and, at times, biometric analyses they supplied, then comparing these sources with her own experimental results in the laboratory. Emily also fed her experimental results back to the biometricians as input into their analyses. The comparative process she used was intended to allow Emily to progressively filter data from several sources in narrowing the search for 'candidate' (or

prospective) genes, as well as to provide multi-pronged evidence in support of results obtained.

Each time the draft genome was updated or she obtained new input from biometricians, Emily sought to interpret how this new material might inform her own comparative analyses. She described *'lingering with the data'* in order to grasp how they might be significant for her project: *'Every new version will actually give you new information that is useful when you analyse them. So it's like, even though it's painful in a way, but it's still very informative'* (final conversation). Drawing on procedures and techniques that were becoming habitualised, Emily typically responded expressively to the new data or analyses. Often this entailed modifying her approach or procedure to take account of the new material. At other times, after consulting her supervisors, she made a judgement not to make changes where new data were not strong or not supported by remaining data. This interplay between habit and expressivity, with guidance from experienced scientists, enabled the students to move their projects forward, as well as to enhance their own skilfulness in practice.

Signs on walls and instructions on equipment also pointed to ways of performing that often had become habitualised for experienced scientists, but not necessarily for students in our study. Diana noted:

[My co-supervisor] *uses this machine and then sometimes he makes it a bit difficult to use, when other people use it very easily. And I get confused and I try it both ways sometimes.... I will just see how my product comes out, and then I'll know.* (initial conversation)

In supporting learning by novices, Megan Watkins notes spatial features, such as 'simple markings in a confined space, architectural design, and signage' can teach (2017, 87). While signage and instructions on equipment are usually intended to teach, other spatially mediated didactics may not intentionally have this purpose. For instance, the design and placement of

handles, knobs and buttons signal their purpose in manipulating equipment. Similarly, gauges, scales and instrument dials indicate readiness for producing measurements. These various affordances can assist novices in learning to use the devices, although they are rarely sufficient for enabling learning. Spatially mediated didactics may, however, serve as prompts when activities are being performed as practice becomes habitualised.

Signs, instructions and measuring devices also call attention to bodies performing through and by means of tangible, material objects that function as components, instruments or ingredients. Objects such as these are bodily perceived and manipulated in performing and in learning. Merleau-Ponty pointed out that objects we use habitually become incorporated into the lived body, such as when biotechnology students repeatedly employ pipettes to measure and dispense required fluids, while avoiding contamination (see Figure). In using such objects, we ‘incorporate them into the bulk of our own body. Habit expresses our power of dilating our being-in-the-world, or changing our existence by appropriating fresh instruments’ ([1945] 1962, 143).

[INSERT FIGURE ABOUT HERE]

Colombetti (2016) distinguishes two closely related senses in which Merleau-Ponty uses this notion of incorporation. The first she terms ‘object-incorporation,’ in which we incorporate objects ‘into the bulk of our own body,’ as Merleau-Ponty expressed it. The second sense Colombetti refers to as ‘habit-incorporation,’ in which we acquire habits through incorporating such objects into the lived body, such as the habit of wearing lab coats that become part of scientists’ bodies in performance. Colombetti considers that ‘object-incorporation can be seen as a special form of habit-incorporation’ (234). She extends Merleau-Ponty’s analysis when she argues that ‘not just the sensorimotor body (the perceiving and moving body) but the affective body too is subject to the process of

incorporation' (231). Affective incorporation is evident when students share in the excitement of new data or feel the stress of failed experiments in learning culturally typical ways of being and doing that shape professional practice.

While objects are incorporated into the lived body in performance, equipment, too, carries out work (see also Latour 1996), including in the background, such as glasshouses regulating conditions in which experimental plants grow or computers performing simulations. Often the work equipment does is only evident through a background hum or dials on monitoring instruments. Other equipment is employed more actively, but still recedes into the background, becoming 'perceptually transparent' (Ihde 2010, 142), such as when scientists look *through* a microscope to see the cells below. In contrast, Don Ihde identifies 'hermeneutic technics' in which an instrument or technology itself becomes the focus of interpretation, such as when a matrix is constructed to record measurements in identifying patterns for explaining observed results. Ihde refers to both perceptually transparent technologies and hermeneutic technics as 'embodiment relations' that make manifest 'the symbiosis of artefact and user within a human action' (136). Colombetti notes Ihde's 'notion of embodiment relations corresponds to what I have called "object-incorporation"' (2016, 235).

For novices, learning to bodily perceive and manipulate a range of tools and equipment presents a challenge in terms of an habitual/expressive dialectic. Based upon a 'thin' habit layer, they must simultaneously learn to use the equipment—including when the task requires that the equipment is perceptually transparent—while also endeavouring to progress with their activities. Young describes a situation in which 'my subjectivity splits between awareness of myself as body and awareness of my aims and projects' (1984, 51). Although her description relates to being pregnant, especially for the first time, this doubling or ambiguity in experiencing the body appears to have resonance with learning in unfamiliar situations (see also Dall'Alba [2009]), in which the body is experienced as 'intimately alien,

strangely mine.’ It also overlaps with Merleau-Ponty’s distinction between ‘the body I have’ and ‘the body I am.’

The habitual/expressive dialectic highlights that the lived body is never fixed nor complete but, rather, always adjusts to emergent situations, continually renewing and rearranging itself in response to others and things it encounters. As Langer notes, ‘the body is the meeting place, so to speak, of past, present and future because it is the carrying forward of the past in the outlining of a future and the living of this bodily momentum as the actual present’ (1989, 32).

The bodily grounds of learning

In this study we have explored learning with and through the lived body as students endeavour to become professionals. Our philosophical-empirical account of what is entailed in learning to embody skilful performance significantly extends, differentiates, and further specifies what is implicated in the notion of ‘learning by doing’ in the broader literature. Specifically, it demonstrates the manner in which learning is grounded in the lived body, as it is through our bodily engagement with world that we learn to appropriate and skilfully perform professional practice. In so doing, our account calls attention to the necessary embeddedness of ‘doing’ something within the overlapping sociomaterial contexts of which it forms a part. Our account also directs awareness to an inevitable interrelationship between epistemological and ontological dimensions of learning to become professionals. Below we bring together features of the bodily grounds of learning we have explored, each of which highlights an aspect of our ambiguous relation with world in learning settings. We also point to theoretical and educational implications for understanding and promoting learning for the professions.

First, our account illustrates that learning to become professionals entails not only learning specific knowledge and skills but, equally, learning ways of being professionals, through embodying the practice in question. In other words, it involves learning

simultaneously to perform professional practice and ways of being the professional in question. One of the ways this can be achieved is through taking up others' ways of being and making them one's own. However, opportunities, constraints, hesitations and accomplishments in bodily performance can be influenced by the contexts in which they occur. Notwithstanding the importance of requirements for skilful performance, lack of openness to diverse others can contribute to an ambiguous relation to one's own capacities that may impact achievements and a sense of a bodily way of being that does not 'fit' well with what is valued. A key implication here is the need for a shift in focus when researching and facilitating learning for the professions. A necessary shift is from acquiring a set of knowledge and skills for subsequent application, to developing ways of being professionals when performing practice, which takes into account the richness and complexity that diverse (aspiring) professionals bring.

Second, the account suggests learning to engage in professional practice requires negotiating the tension between the perceiving, moving, feeling body we have and the social, cultural body subject we aspire to be, namely, practitioners skilfully performing professional practice. This negotiation involves 'losing oneself in the drama' of practice through employing 'the body I have,' while also committing the 'body I am.' In this negotiation, the 'body I have' can fall short of the 'body I am' striving to be. Attunement to the world through bodily perception, motility and emotion shapes the body as it performs—both individually and in concert with others. A central implication is the importance of understanding how to promote learning that takes place through negotiating this tension towards skilful professional practice.

Third, the account proposes that learning to become professionals—including learning to 'do' the performance and the associated intellectual development—occurs through a continuous dialectic between habitual and expressive layers of the lived body in performing professional practice. The habitual layer projects a customary way of performing,

while the expressive layer constantly adjusts past ways of performing practice to new situations and particularities. The habitual-expressive dialectic is likely to be especially active among novices, given their relative inexperience. This bodily performing occurs through and by means of material objects in symbiosis with (aspiring) practitioners, including spatially mediated didactics, as well as with guidance from others. Not only are material objects incorporated into the body in performance, but affective incorporation occurs in learning culturally typical ways of being and doing. A crucial implication here is to understand and facilitate the ongoing bodily dialectic that enables aspiring practitioners to perform professional practice, while at the same time constantly developing it.

In conclusion, in order to more fully understand what is entailed in learning to embody skilful performance, it is important we take more seriously how the body subject is implicated in learning. More particularly, it is through the lived body we come to appropriate particular ways of being and performing professional practice. Learning through the lived body takes place through continuous negotiation between the body we have and the body subject we aspire to be, as well as through the dialectic between the habitual-expressive layers of the body. In order to advance our understanding still further, additional conceptual distinctions and empirical investigations are necessary, as well as developing research methods attentive to the variation and complexity of the bodily grounds of learning.

Funding

This research was supported by grant number DP110104382 from the Australian Research Council.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

- Allen-Collinson, J. and H. Owton. 2015. "Intense Embodiment: Senses of Heat in Women's Running and Boxing." *Body & Society* 21(2): 245-268.
- Barnacle, R. 2009. "Gut Instinct: The Body and Learning." *Educational Philosophy and Theory* 41(1): 22-33.
- Barnacle, R., and G. Dall'Alba. 2017. "Committed to Learn: Student Engagement and Care in Higher Education." *Higher Education Research and Development* 36(7): 1326-1338.
- Bischor, D. 2011. "Animated Bodies in Immunological Practices: Craftsmanship, Embodied Knowledge, Emotions and Attitudes Toward Animals." *Human Studies* 34: 407-429.
- Bresler, L. 2004. *Knowing Bodies, Moving Minds: Towards Embodied Teaching and Learning*. Dordrecht: Kluwer Academic.
- Burwood, S. 2012. "Turned into Body by the Other." In *Embodied Selves*, edited by S. Gonzalez-Arnal, G. Jagger, and K. Lennon, 119-138. London: Palgrave Macmillan.
- Casey, E. 1998. "The Ghost of Embodiment: On Bodily Habitudes and Schemata." In *Body and Flesh: A Philosophical Reader*, edited by D. Welton, 205-225. Malden, MA and Oxford: Blackwell.
- Colombetti, G. 2016. "Affective Incorporation." In *Phenomenology for the Twenty-First Century*, edited by J.A. Simmons and J.E. Hackett, 231-248. London: Palgrave Macmillan.
- Cravey, A.J. and M. Petit. 2012. "A Critical Pedagogy of Place: Learning Through the Body." *Feminist Formations* 24(2): 100-119.
- Dall'Alba, G. 2009. *Learning to be Professionals*. Dordrecht: Springer.
- Dall'Alba, G., J. Sandberg, and R.K. Sidhu. 2018. "Embodying Skilful Performance: Co-Constituting Body and World in Biotechnology." *Educational Philosophy and Theory* 50(3): 270-286.
- de Freitas, E. 2016. "Material Encounters and Media Events: What Kind of Mathematics Can a Body Do?" *Educational Studies in Mathematics* 91(2): 185-202.
- Dewey, J. 1938. *Experience and Education*. New York, NY: Kappa Delta Pi.
- Fox, M. 2015. "Learning by Doing." In *Sage Encyclopedia of Economics and Society*, edited by F.F. Wherry and J.B. Schor. Thousand Oaks, Sage. doi: 10.4135/9781452206905.n404
- Ghilay, Y., and R. Ghilay. 2015. "TBAL: Technology-Based Active Learning in Higher Education." *Journal of Education and Learning* 4(4): 10-18.

- Gilbert, J. 2013. "The Pedagogy of the Body: Affect and Collective Individuation in the Classroom and on the Dancefloor." *Educational Philosophy and Theory* 45(6): 681-692.
- Gonzalez Arnal, S., G. Jagger, and K. Lennon, eds. 2012. *Embodied Selves*. Basingstoke, Hampshire & New York: Palgrave Macmillan.
- Green, B. 2009. "The Primacy of Practice and the Problems of Representation." In *Understanding and Researching Professional Practice*, edited by B. Green, 39-54. Rotterdam: Sense.
- Green, B., and N. Hopwood, eds. 2015. *The Body in Professional Practice, Learning and Education*. London: Springer.
- Hackathorn, J., E.D. Solomon, K.L. Blankmeyer, R.E. Tennial, and A. M. Garczynski. 2011. "Learning by Doing: An Empirical Study of Active Teaching Techniques." *Journal of Effective Teaching* 11(2): 40-54.
- Harding, S.G. 2015. *Objectivity and Diversity: Another Logic of Scientific Research*. Chicago: University of Chicago Press.
- Heidegger, M. (1927) 1962. *Being and Time*. Translated by J. Macquarrie and E. Robinson. New York: SCM Press.
- Holloway, K.F.C. 2011. *Private Bodies/Public Texts: Race, Gender, and a Cultural Bioethics*. Durham, NC: Duke University Press.
- Hopwood, N., D. Rooney, D. Boud, and M. Kelly. 2016. "Simulation in Higher Education: A Sociomaterial View." *Educational Philosophy and Theory* 48(2): 165-178.
- Hui, A., T. Schatzki, and E. Shove. eds. 2016. *The Nexus of Practices: Connections, Constellations, Practitioners*. Abingdon and New York: Routledge.
- Ihde, D. 2010. "A Phenomenology of Technics." In *Technology and Values: Essential Readings*, edited by C. Hanks, 134-156. Chichester: Wiley-Blackwell.
- Ivinson, G. 2012. "The Body and Pedagogy: Beyond Absent, Moving Bodies in Pedagogic Practice." *British Journal of Sociology of Education*, 33(4): 489-506.
- Kelly, M., R. Ellaway, A. Scherpbier, N. King, and T. Dornan. 2019. "Body Pedagogics: Embodied Learning for the Health Professions." *Medical Education* 53(10): 967-977.
- Kemmis, S. and R. Mutton. 2012. "Education for Sustainability (EfS): Practice and Practice Architectures." *Environmental Education Research* 18(2): 187-207.
- Langer, M.M. 1989. *Merleau-Ponty's "Phenomenology of Perception": A Guide and Commentary*. London: Palgrave Macmillan.
- Latour, B. 1996. "On Intersubjectivity." *Mind, Culture, and Activity* 3(4): 228-245.

- Leigh, J., ed. 2019. *Conversations on Embodiment Across Higher Education: Teaching, Practice and Research*. London: Routledge.
- McCuaig, L. and P.J. Hay. 2013. "Towards an Understanding of Fidelity Within the Context of School-Based Health Education." *Critical Public Health* 24(2): 143-158.
- Merleau-Ponty, M. (1945) 1962. *Phenomenology of Perception*. Translated by C. Smith. London: Routledge and Kegan Paul.
- Mulcahy, D. 2015. "Body Matters: The Critical Contribution of Affect in School Classrooms and Beyond." In *The Body in Professional Practice, Learning and Education*, edited by B. Green and N. Hopwood, 105-120. London: Springer.
- Negro, C., N. Merayo, M.C. Monte, A. Balea, E. Fuente and A. Blanco 2019. "Learning by Doing: Chem-E-Car® Motivating Experience." *Education for Chemical Engineers* 26, 24-29.
- Noddings, N. 2005. *The Challenge to Care in Schools: An Alternative Approach to Education*. 2nd ed. New York: Teachers College Press.
- O'Loughlin, M. 2006. *Embodiment and Education: Exploring Creatural Existence*. Dordrecht: Springer.
- Pierce, J. and H. Widen. 2017. "Visceral Pedagogy: Teaching Challenging Topics Emotionally as Well as Cognitively." *Journal of Geography* 116(2): 47-56.
- Probyn, E. 2004. "Teaching Bodies: Affects in the Classroom." *Body & Society* 10(4): 21-43.
- Reid, J. and D.M. Mitchell. 2015. "Inhabiting a Teaching Body: Portraits of Teaching." In *The Body in Professional Practice, Learning and Education*, edited by B. Green and N. Hopwood, 89-104. London: Springer.
- Santoro, D.A. 2015. "Philosophizing About Teacher Dissatisfaction: A Multidisciplinary Hermeneutic Approach." *Studies in Philosophy and Education* 34(2): 171-180.
- Schön, D.A. 1983. *The Reflective Practitioner: How Professionals Think in Action*. New York: Basic Books.
- Sheets-Johnstone, M. 2015. "Embodiment on Trial: A Phenomenological Investigation." *Continental Philosophy Review* 48: 23-39.
- Shilling, C. 2010. "Exploring the Society-Body-School Nexus: Theoretical and Methodology Issues in the Study of Body Pedagogics." *Sport, Education and Society* 15(2): 151-167.
- Skulmowski, A. and G.D. Rey. 2018. "Embodied Learning: Introducing a Taxonomy Based on Bodily Engagement and Task Integration." *Cognitive Research: Principles and Implications* 3:6.

- Standal, Ø.F. and G. Engelsrud. 2013. "Researching Embodiment in Movement Contexts: A Phenomenological Approach." *Sport, Education and Society* 18: 154-166.
- Stoller, S. 2010. "Expressivity and Performativity: Merleau-Ponty and Butler." *Continental Philosophy Review* 43: 97-110.
- Sutherland, A. 2013. "The Role of Theatre and Embodied Knowledge in Addressing Race in South African Higher Education." *Studies in Higher Education* 38: 728–740.
- Swartz, A.L. 2012. "Embodied Learning and Patient Education: From Nurses' Self-Awareness to Patient Self-Caring." *New Directions for Adult and Continuing Education* 134: 15–24.
- Thomson, I. 2001. "Heidegger on Ontological Education, Or: How We Become What We Are." *Inquiry* 44(3): 243-268.
- Todd, S. 2016. "Education Incarnate." *Educational Philosophy and Theory* 48(4): 405-417.
- Wagner, A.E. and R.A. Shajhahan. 2015. "Centering Embodied Learning in Anti-Oppressive Pedagogy." *Teaching in Higher Education* 20(3): 244–254.
- Watkins, M. 2017. "Can Space Teach? Theorising Pedagogies of Social Order." *Geographical Research* 55(1): 80–88.
- Wolkowitz, C. 2006. *Bodies at Work*. Thousand Oaks, Ca and London: Sage.
- Young, I.M. 1984. "Pregnant Embodiment: Subjectivity and Alienation." *Journal of Medicine and Philosophy* 9: 45-62.
- Young, I. M. 1990. "Throwing Like a Girl: A Phenomenology of Body Comportment, Motility, and Spatiality." Chap 8 in *Throwing Like a Girl and Other Essays in Feminist Philosophy and Social Theory*, 141-159. Bloomington: Indiana University Press.

Figure. Extending the body with instruments