Professional-Scientific Education: Rethinking the Concept of Knowledge
a Cultural-historical 'Recontextualization' Perspective

Abstract

Throughout the second half of the twentieth century the mode of knowledge production diversified and now embraces disciplinary and inter- and trans-disciplinary knowledge. This chapter addresses the implications of these changes for the concept of professional-scientific education by firstly creating a conversation between two different perspectives – 'reflective practice' and the 'trinary' – on professional scientific education. Secondly, critically appraising these perspectives in relation to ongoing changes in knowledge production. Thirdly, offering a new perspective on professional-scientific knowledge – 'continuous recontextualisation' – which incorporates the insights of the reflective and trinary positions, anticipates future changes in knowledge production and, importantly, relates both to work practice.

professional-scientific knowledge, reflective practice, the trinary, recontextualization, machine learning.

Introduction

The mid-twentieth century consensus about professional-scientific knowledge was famously challenged by Donald Schön in his books *The Reflective Practitioner: How professionals think in action* (1983) and *Educating the Reflective Practitioner* (1987). Up to that point in time, professional-scientific knowledge, in other words, the knowledge that constituted the basis of those disciplines in higher education which facilitate the first phase of professional formation in a particular field, for example, architecture, engineering, medicine, pharmacy etc., had been predicated globally and unproblematically on what Schön referred to as 'technical rationality.' This concept was based on two interrelated assumptions: first, the objectivity of scientific knowledge and methods of inquiry resulted in the production of context-free knowledge and second, that the purpose of programmes of professional-scientific education was to teach such knowledge and methods as the basis to prepare people to enter their chosen profession. Technical rationality therefore conceived of the relationship between theory and practice in linear and unidirectional terms, in other words, the primary task facing a professional was to *apply* the professional-scientific knowledge they had acquired through their university studies in

practice. In contrast, Schön maintained there was always a *reflective* dimension to human thinking and action, because professionals had to take account of the circumstances or context of their action and determine how to proceed on a case-by-case basis rather than to merely apply pre-acquired knowledge, and this had implications for the extant professional-scientific conception of knowledge and pedagogy. Over the intervening years, Schön's argument about the limitations of technical rationality and the virtues of reflective practice has been duly celebrated and adumbrated (see e.g. Boud and Solomon 2001; Payne 2002; Taylor and White 2000; Winter and Maisch 1996) and also subject to critique (Bradbury *et al.* 2009; Eraut 1995; Winch 2010). One highly regarded recent critique is found in Michael Young and Johan Muller's edited collection *Knowledge, Expertise and the Professions* (2014). Here, Young and Muller, drawing on arguments contained in previous publications (Young 2007; Young and Muller 2014), update the original technical rational position that professionals apply the knowledge acquired in education to their practice, via their concept of the 'trinary', to overcome what they felt was the incipient relativism and a-theoretical stance ushered in by the global embrace of Schön's concept of reflective practice.

Taking the different positions about knowledge represented by Schön and Young and Muller as its starting point, the chapter rethinks the concept of knowledge in professional-scientific education. It does so in the following way. The chapter starts by offering a succinct summary of Schön's position and Young and Muller's critique, with passing reference to their respective intellectual influences Dewey, Durkheim and Bernstein. The chapter affirms aspects of Schön and Young and Muller's respective positions, before problematizing their positions by following Jonsen and Toulmin (1988) and making the case for the inclusion of knowledge as 'axioms' and 'maxims' in professional-scientific education since the latter constitutes the resolution of the theory–practice relationship in work contexts. The chapter then locates the concept of professional-scientific knowledge in the changes that have occurred over the last half century in knowledge production in higher education and in industry, as well as the status of knowledge in society as a result of the 'ongoing scientificization of society and the socialization of science' (Rein and Wildt 2022). It does so by discussing new modes of, (Gibbons *et al*. 1994) and sites for knowledge production (Nonaka and Takeuchi 1995), and also how the transition from modernity to post-modernity has introduced a more explicit *performative* dimension to the status and role of knowledge in societies (Bauman 1987). The chapter argues that the unifying thread between both developments is they have drawn attention to the contextual, rather than context-free, basis of professional-scientific knowledge, and the way in which such knowledge is reused and regenerated as a resource in professional-scientific curricula and professional practice. The chapter then explores this contention by firstly,

introducing a conception of knowledge as lying on a spectrum encompassing disciplinary, interdisciplinary and transdisciplinary knowledge, including its research- and company-based expressions. Secondly, drawing on my own work (Guile 2010; 2014; 2018) it argues that the implication of the spectrum is to allow us to adopt a new view of the relationship between theory and practice as a process of the *continuous recontextualization of knowledge and practice*. The chapter concludes by pursuing the implications of this claim with respect to the emergence of 'Machine Learning' (Royal Society 2017).

The concept of professional-scientific knowledge and its relationship to practice

Schön's 'epistemology of practice'

The original impetus for Schön's epistemology of practice was the assumption about the relationship between theory and practice in programmes of professional education in American universities in the 1980s. Schön (1987: 3) argued that such programmes left students floundering between the 'high ground' of theory where the solution to all professional problems is found through research-based theory and technique and the 'swampland' of practice where there are messy problems that defy technical solution. This dilemma, for Schön, had two sources. The first was the legacy of 'technical rationality', that is, an 'epistemology of practice based on positive philosophical assumptions which was built into the heart of the model university' (Schön 1987: 3). The cornerstone of this epistemology is the assumption that the scientific research techniques are independent of their context of use and can therefore be applied un-problematically to resolve any social, economic or political problems. The second source of the problem was 'an awareness of indeterminate, swampy zones of practice that lie beyond its canons' (Schön 1987: 3) and a recognition that professional education poorly equipped professionals to deal with such problems.

The solution to the separation of theory and practice in professional education that Schön (1987: 22-37) proposed was based on an epistemology of practice which he defined as 'reflection-on-action'. This epistemology reflected what Schön (1987: 36) referred to as a 'constructionist'[1] view of the reality with which professionals deal. By this Schön meant, the problems of practice are never pre-given as technical rationality assumed, and thus

[1] Compared with contemporary discussion, Schön uses the term constructionist in a rather idiosyncratic way to refer to the ideas that professionals mentally formulate about the problems they work on.

susceptible to resolution through the application of the scientific method of inquiry. Instead, professionals have to construct their interpretation of those problems as well as the modes of competence required to resolve them, and their solutions are never 'in the book'; they have to be solved through a 'kind of improvization' and a testing of the chosen strategies (Schön 1987: 5).

The implication of Schön's epistemological conception was a shift in professional education away from a curriculum based on the acquisition of theories and the application of research-based modes of inquiry, towards a curriculum that facilitated the development of professional artistry through a 'reflective practicum' (Schön 1987: 18). Further naturalizing Dewey's (1910) naturalization of the scientific method of inquiry in *How We Think* (Guile 2010), Schön (1987) argued that a reflective practicum should draw on case histories, exemplars and precepts and move through the cyclical process of inquiry Dewey advocated. The design of this type of curriculum was to support professionals to recognize and know how to apply standard rules, to reason from generalized rules to problematic cases and to learn how to improvize to respond to uncertain or conflicting situations of practice.

Young and Muller's 'trinary'

Writing nearly thirty years later, Young and Muller (2014: 10) note that the enduring impact and popularity of Schön's argument can be easily gauged by virtue of if being hard not to 'come across a programme in initial or further Professional Development that does not somewhere mention his idea of the 'reflective practitioner' in much of global higher education'. Young and Muller are, however, deeply troubled by the uptake of Schön's epistemology of practice because it is, for them, a more regressive than progressive development. They define Schön's epistemology of practice as an 'anti-intellectualist stance' that could be seen as a 'nostalgic return to the practice of the medieval craft guilds but without their specialized focus'. Furthermore, they observe that the 'irony' of this position is that the 'only way the specialized knowledge of professions can be recognized in Schön's approach is through the element of professional education and knowledge that his model excludes' (Young and Muller (2014: 11).

Drawing on their previous separate (Muller 2000; Young 2007) and joint work (Young and Muller 2014; 2016), they update their previous engagement with the work of Basil Bernstein to develop an alternative to Schön's epistemology of practice. Young and Muller argue that in his earlier work Bernstein drew on Durkheim to develop a classification of types of theoretical knowledge based on a prior differentiation between theoretical and practical (or common sense) knowledge, or in his terms, vertical and horizontal discourses. They note, however, he recognized in his later work

that these binary categories 'were not adequate to grasping what are the increasingly dominant forms of knowledge in modern societies' (Young and Muller (2014: 13). This is because professional knowledge is both theoretical and practical, in other words, operates in a context with a purpose outside itself, and professional knowledge is always sectoral since it relates to specific occupational sectors such as health, transport and education.

To pursue this insight Bernstein broadened, according to Young and Muller (2014: 13), his original conception of theoretical knowledge. He coined the term *singulars* to refer to separate or bounded forms of knowledge, such as mathematics or physics, that provide rules that are general and applicable in all situations, for example, the laws of thermo-dynamics; and, *regions* to refer to knowledge that is only applicable in certain practical situations, in Bernstein's term, a field of practice, and that is responsible for shaping the development of professional expertise, for example, in engineering the laws of thermo-dynamics are purposive and contextual by providing rules to guide measurement (such as temperature, volume, and pressure) of the field of energy and its capability to operate effectively. Retaining the Durkheimian attachment to a conception of science, which is also shared by Bernstein, as objective truth unsullied by material considerations, Young and Muller (2014: 13) conceive of singulars as forms of knowledge that develop for 'their own sake'. They elaborate and extend Bernstein's definition of regions by firstly, arguing that by bringing together or re-contextualizing several disciplines in relation to a field of practice like construction or medicine, regions are the 'sources of current and future professional knowledge' because they '*enable* (italicization DG) professionals to reconceptualize real-world practices and processes in new ways related to new purposes' (Young and Muller (2014: 13). As a consequence, professional knowledge has three components: know that knowledge, which is the basis of the content selected from singulars; know how knowledge, that allows content from different singulars to be brought together to contribute to the development of regions; and the 'canonized body of specialized professional knowledge that represents the stable reservoir gleaned from earlier 'applied' research, which can, at times, augment not only the knowledge base of the profession, but add to new knowledge in one of the parent singulars' (Young and Muller 2014: 13). A paradigmatic illustration being engineering science, since it has generated its own scientific literature and communities that have global jurisdiction over the accreditation of engineers.

Young and Muller culminate their elaboration and extension of Bernstein by arguing that his innovation is to conceptualize an old problem – the relationship between theory and practice – in a new way that also enables us to characterize this relationship as lying at the heart of professional knowledge. This innovation, according to Young and Muller (2014: 14), is to

extend the familiar binary distinction between theory and practice into a three-fold distinction:

- Singulars – the rules, methods and boundaries that define a discipline.
- Regions, which combine disciplines, selecting, pacing and sequencing knowledge from them in relation to specific purposes in a field of practice (for example, combining parts of physiology and physics and stable contextually derived knowledge to form biomechanics, which is part of the professional curriculum of physiotherapists);
- Fields of practice, which are the specialized practical contexts in which professionals practice – that is, exercise knowledgeable and reasoned judgments as professionals, by drawing on, often tacitly, their acquired stock of specialized professional knowledge.

Epistemology of practice and the trinary: a missing conversation?

The rather curt dismissal of Schön as anti-intellectual and having a romantic attachment to a craft conception of knowledge and professional practice conveys the impression that his epistemology of practice and Young and Muller's trinary are fundamentally incompatible. This would be an unfortunate impression since there are a number of very good reasons why their respective positions on the relationship between theory and practice are compatible, but insufficient to fully grasp the contemporary dynamics behind that forever changing relationship. To understand why, it is necessary to further clarify Schön's solution to the problem with technical rationality since that is the root of his epistemology of practice and Young and Muller's critique. Schön's (1987: 13) solution was to:

> ….turn the relationship between competence and professional knowledge upside down. We should start not by asking how to make better use of research-based knowledge but by asking what we can learn from a careful examination of artistry.

He used his critique of the objectivist basis of technical rationality and his affirmation of the constructionist basis of the reflective practicum to argue for the latter to be privileged over the former in the design of professional education courses. This solution implies an agnostic, rather than an anti-intellectualist or craft, stance on Schön's part as regards the knowledge taught in professional education. Schön's concern is instead firstly, to

highlight that the research-based knowledge of professional education courses is not, as Young and Muller imply, coterminous with professional practice because there are other forms of knowledge and considerations in play and, as such, does not constitute an 'axiom' that professionals can use to deduce what is the case from universal rules (Jonsen and Toulmin 1988: 23). Secondly, to draw attention to the pedagogic practice – reflection – that in his opinion facilitates the formation of judgement through inferring from 'maxims' (i.e. practical exemplars) what might be the case, in professional work contexts. In doing so, Schön is drawing attention to two issues that are entirely missing from Young and Muller's proposed solution to the relationship between theory and practice – work as a site of knowledge production, though in Schön's case only on an individual basis, and pedagogy in educational and work contexts as a means to facilitate the development of professional-scientific knowledge. Set against these oversights, Young and Muller's elaboration and extension of the concept of singulars and regions, despite my unease with the overly idealized enlightenment sensibility that underpins the former (singulars as the search for knowledge for its own sake) and the derivative status attributed to the latter, offers a more rounded and nuanced conception of the knowledge taught in programmes of professional education and its relationship to professional practice, compared to Schön's casual dismissal of that knowledge. Moreover, Young and Muller affirm the constitutive role that such knowledge plays in extending what, following Vygotsky (1997), can be referred to as learners' 'higher mental functions', for example, disciplinary conceptualization, symbolization and meta-cognitive reflection etc., which they use to engage in conceptual and reflective thinking in higher education and subsequently in professional practice, albeit in slightly different ways.

Unfortunately, Young and Muller are inclined to make sweeping assertions about singulars and regions, for example, that singulars are context-free and regions are coterminous with the knowledge required for professional practice and, moreover, such knowledge enables professionals to reconceptualize real-world practices and processes in new ways related to new purposes. In the case of the first observation, there is an unacknowledged tension in Young and Muller's position. They both accept that singulars and regions are underpinned by 'codes' (Ward 1994) which enable forms of knowledge to be classified and verified and recontextualized as content into curricula. Yet the codes underpinning singulars and regions serve as normative conventions that facilitate their communicability and further development. Given that such codes are human creations, they clearly constitute one context in which singulars and regions are debated and shared and curricula constitute another context.

In the case of the second observation, work on knowledge cultures (Nerland 2008; Knorr Cetina 2010) and practices (Styhre 2009) reveals that,

on the one hand, a complex, multi-faceted and even transgressive relationship exists between regions, practice-generated knowledge and legal considerations and obligations; and, on the other hand, different forms of knowledge are embedded in work environments and embodied in professionals' forms of knowing. These observations can be illustrated with reference to a study of the remodelling of two public libraries to create access for people with disabilities, and to strengthen the buildings against earthquakes in a way that was professionally sound (Guile 2011b). The solution the project team, which comprised architects, structural and fabrication engineers, representatives of various preservationist and community constituencies, and building inspectorate, ultimately produced had to take account of the knowledge already embedded in the design of the building and embodied in the participants. The challenge confronting the team was to commingle aspects of architectural design and specialist engineering knowledge (i.e. structural, mechanical), local concerns to preserve the integrity of the original design, and building codes, in other words, legal and technical specifications pertaining to materials, spatial and environmental sustainability considerations, to agree a solution to the dual problem they confronted. To do so, each contributor 'recontextualized' their knowledge to produce a solution that addressed the task-in-hand (Guile 2011b: 110). The knowledge contained within a region constituted therefore a resource, in conjunction with other considerations, the team used to reimagine the design and safety of a building, rather than an invariant set of rules brought to bear on their deliberations.

Furthermore, the process of professionals using regions to reconceptualize real-world problems in new ways is more multi-faceted and less invariant than is implied by Young and Muller. Research on 'user generated innovation' by von Hipple (2006) has, for example, revealed how innovation is rapidly becoming 'democratized' as users, aided by improvements in computer and communications technology, develop their own new products and services. One notable example being the creation of Open-Source Software where innovating users – both individuals and firms – freely shared their innovations with others, creating user-innovation communities and a rich intellectual-commons. Open-Source Software is without a doubt a reconceptualization of real-world practices in new ways and for new purposes that has had massive benefits for academic, professional and lay communities. The innovation stemmed however from users' frustrations with proprietary software rather than regions enabling the innovation to occur, though they are likely to have been a contributory resource to that process.

The above example and discussion can be used to reveal the insights and oversights of Schön's epistemology of practice and Young and Muller's trinary. In arguing for a model of rationality that emphasized maxims and

judgemental interpretation, as opposed to a scientific model predicated on axioms and determinate rules that spelt out what was the case, Schön highlighted why there is a case to include some examples of practice-based knowledge in programmes of professional-scientific education. Its inclusion counters the idea that students might otherwise develop that theoretical knowledge is coterminous with a field of practice and, instead, allow them to appreciate that theoretical knowledge is part of an expert's 'capacity for action' (Guile and Unwin, forthcoming). He omitted, however, to acknowledge that the knowledge (i.e. regions) provided by such programmes nevertheless constituted a resource that reflective practitioners still needed. In contrast, in combatting this oversight Young and Muller demonstrate the continuing relevance of theoretical knowledge to programmes of professional-scientific education; unfortunately, they eviscerate the actual field of practice from their proposed solution to the relationship between theory and practice and leave us, instead, with a de-contextual field of practice – the region as defined in professional-scientific knowledge as the field.

The lesson to be drawn from the above conversation between Schön's epistemology of practice and Young and Muller's trinary is that they both provide important and compatible, but nonetheless insufficient, insights into both the concept of professional-scientific knowledge and its relationship to practice. To understand why, it is necessary to locate their respective positions on professional-scientific knowledge in relation to the ongoing scientificization of society and the socialization of science – issues whose current manifestations post-date Schön but which, curiously, Young and Muller leave out of their discussion of regions, even though they have addressed them in earlier work (Young 1998; Muller 2000).

The scientificization of society and the socialization of science and professional-scientific knowledge

The scientificization of society and the socialization of science was first predicted by Marx in the 'Fragment on Machines' in the *Grundrisse* (1939/1973). Here, Marx engaged in a thought experiment, based on his concept of the 'general intellect', about the future direction of science in capitalist societies; a speculation that subsequently inspired debates about the continued deployment of science in all spheres of society resulting in either mass automation and mass unemployment or new forms of the production and utilization of knowledge, new forms of work and political action (see Fuchs 2019 for an overview). From the perspective of this chapter's interest in professional-scientific knowledge and the relationship between theory and

practice, the latter debate about the ongoing scientificization of society and the socialization of science is more relevant. These processes have, as Rein and Wildt (2022) observe, resulted in internal and external challenges to professional-scientific knowledge. In the case of the former, as 'scientific development itself moves beyond the boundaries of the subjects', since there have been significant 'changes in the institutional structure of the universities in the relations between disciplinary and interdisciplinary work', with inevitable knock-on implications for professional work: a development partly encapsulated by Young and Muller's term – regions. In the case of the latter, scientificization has resulted in new modes of, and sites for, knowledge production outside universities.

New modes of knowledge production

In their book *The New Production of Knowledge* (1994), Gibbons and colleagues pursue the implications of the scientificization of society and the socialization of science by going beyond firstly, the classic arguments about a general theory of knowledge (Schlick 1974) that was predicated on a particular 'scientific' conception of empirical evidence and its relationship to the truth of a theory; and secondly, Young and Muller's formulation of the trinary (i.e. the divide between common-sense knowledge, singulars and regions), even though their book was written over two decades beforehand. They argue the 'parallel expansion in the number of potential knowledge producers on the supply side and the expansion of the requirements of specialist knowledge on the demand side have created the conditions for the emergence of a new mode of knowledge production' (Gibbons *et al*. 1994: 13). They define this new mode of knowledge production, which is occurring outside of higher education and its longstanding conceptions of the scientific method, as *transdisciplinarity* and identify two expressions of this development: one undertaken by firms or networks of firms in conjunction with university partners and therefore drawing to some considerable extent on professional-scientific knowledge and the scientific method; and one accomplished by firms or networks of firms without university partners where professional-scientific knowledge is embedded in technology and embodied in professional activity, which in many instances is performed tacitly.

To clarify why this is the case, Gibbons and colleagues contrast traditional disciplinary-based research (single or interdisciplinary / singular or region) which has been conducted in universities, with transdisciplinarity. They coin the term 'Mode 1 knowledge production' to summarize the cognitive and social norms that have traditionally influenced the production, legitimation and diffusion of scientific knowledge where: problems were set

and solved in a context that is governed by the academic community alone; knowledge in a given field was accumulated through building on or adding to the existing stock of knowledge through a high degree of homogeneity of knowledge producers; and, standards of scientific excellence were decided in accordance with a process of rigorous, anonymous academic peer review as the main form of public accountability (Guile 2010: 29-30). Mode I could therefore refer to disciplinary or interdisciplinary knowledge.

They coin the term 'Mode 2' to describe the mode of production of knowledge they claim is being developed now in advanced industrial societies to support economic, social and political changes. This new mode of knowledge production is firstly produced in a 'context of application', in other words, a situation 'where knowledge is developed for and put to use, while results – which would have traditionally been characterized as applied – fuel further theoretical advances' (Gibbons *et al*. 1994: 19). Moreover, the process of research is being guided by principles of design originally developed in an industrial context, rather than traditional scientific inquiry. Secondly, the Mode 2 research agenda is set in contexts of application through a process of continuous negotiation of the needs, interests and specifications of stakeholders, such as universities, industry and government: hence it has a multi-faceted knowledge structure. A classic example of Mode 2 knowledge production according to Gibbons *et al*. (1994: 20–22) is the links that have been established between the aeronautical industry and university-based physics departments in the attempt to build a 'hypersonic aircraft'. The success of this project was dependent on solving the problem of propulsion generated by an aerobic motor that 'uses air as the combustant rather than oxygen mass', which could only be achieved by taking account of the prior developments in technology which structure the context of application.

A further implication of Mode 2 is that firms are, in many instances, the primary site for research and development (Gibbons *et al*. 1994: 25) because commercial applications are developed in companies or business units. Mode 2 knowledge therefore, unlike Mode 1 knowledge, grows heterogeneously, since an integral element is the 'tacit knowledge' held by communities of professionals and this constitutes the critical resource for its production (Gibbons *et al*. 1994: 45). In making the above observation, Gibbons and colleagues anticipated by twelve months the argument presented by Nonaka and Takeuchi in *The Knowledge Creating Company* (1995). In a nutshell their argument was that organizations innovate by creating new knowledge and information 'from the inside out, in order to redefine both problems and solutions and, in the process, to re-create their environment' (Nonaka and Takeuchi 1995: 56). The inescapable element facilitating knowledge production inside firms is, according to Nonaka and Takeuchi

(1995: 60) the reservoir of 'subjective, bodily, and tacit aspects of knowledge' held by individuals in workplaces.

Drawing on their extensive experience of supporting the journey of Japanese companies, such as Toyota and Honda when they were engaged in new product development, Nonaka and Takeuchi (1995: 56–70) argue that the 'cornerstone of our epistemology is the distinction between tacit and explicit knowledge [and that] the key to knowledge creation lies in the mobilization and conversion of tacit knowledge', and they define knowledge creation in firms as a spiralling of interactions between explicit and tacit knowledge that turns tacit knowledge about products, services and systems into explicit knowledge. This spiral consists of four phases (Nonaka and Takeuchi 1995, p. 62-72). In the first phase, tacit knowledge is formed as professionals share experiences through the creation of mental models and technical skills. In the second phase, explicit knowledge is created as professionals articulate tacit knowledge in workplaces into explicit concepts in the shape of metaphors, analogies, concepts, hypotheses or models. In the third phase, professionals combine different types of explicit knowledge through a process of 'systemizing concepts' (i.e. the common understandings that have been built up) into a 'knowledge system', to construct a body of knowledge they can use to reconfigure the production process. Finally, professionals operationalize and internalize the new form of explicit knowledge. Over the intervening years, some writers have further developed the idea of firms as sites for knowledge (Davenport and Prusak 1998; von Grogh *et al*. 2000), some writers have extended the idea to analyse innovation and knowledge creation in regions (Bathelt *et al*. 2017) and other writers have argued capitalism now has a 'cognitive' dimension based on knowledge 'capture' in work teams (Moulier Boutang 2011).

At first sight, Gibbons and colleagues and Nonaka and Takeuchi's reference to tacit knowledge as a key resource in new modes of knowledge production may appear to imply an anti-scientific sensibility on their behalf, until we recall that when Polanyi originally invoked the aforementioned term in *Personal Knowledge* (1958) he was drawing attention to scientists' embodied practical (i.e. tacit) knowledge, rather than some form of common sense knowledge (Guile 2010: 48-9). Polanyi's usage suggests therefore that the professionals that Gibbons and colleagues and Nonaka and Takeuchi are referring to have commingled theory from different branches of engineering or science with their practice-based experiences in a distinctive way to generate their own 'form of knowing' (Guile 2018: 18). One way of expressing this process is to say that professionals are ``making conceptually-structured professional (or, alternatively practical) judgements in context-specific circumstances, rather than applying their theoretical knowledge practically or taking practical decisions that lack any conceptual content' (Guile 2014: 88). The implications of the above observations will be returned to later.

Despite drawing attention to the way in which firms constitute sites for knowledge production and the facilitatory resources and processes, Gibbons and colleagues and Nonaka and Takeuchi pay less attention to the reorganization of work that predated both these developments. One key development from the late 1980s onwards has been, as Grabher (2003) noted, the redesign of work in industries around the concept of the interprofessional project team, for example, the automobile industry (Midler 1995), or the design of industries or firms around the concept of the project, for example, the creative industry (Caves 2000) or professional service/consulting firms (Empson *et al.* 2015). Taken together, these developments, which are predicated on a functionally integrated rather than functionally differentiated division of labour, have changed significantly the context for professional work – professionals are increasingly positioned to collaborate with one another (Adler and Heckscher 2006) – and furthermore, have given rise in institutes of higher education to the introduction of a new region – project management (Morris *et al.* 2012). The cumulative effect of these developments is the continual creation of contexts for knowledge production where professionals are required to relate different forms of knowledge to one another. This constitutes a radically different conception of a field of practice compared with Bernstein's original invocation of that term and Muller and Young's assumption that regions are coterminous with fields of practice.

Revisiting the missing conversation

The emergence of new modes and sites of knowledge production allow us to revisit with a fresh eye Schön's epistemology of practice and Young and Muller's trinary. In the case of the former, the development of knowledge in its context of application has elevated the importance of the tacit and embodied knowledge held by members of the different scientific and professional communities, far beyond the individual focus of Schön's argument about reflective practice. Tacit and embodied knowledge has become an integral and collective resource, so long as they can be converted and formalized into some form of a knowledge-based resource to contribute to the production of transdisciplinary knowledge.

In the case of the trinary, the emergence of transdisciplinary knowledge production appears to call into question the whole edifice of the conventional conception of science (singulars and regions). There are however, as Muller (2000: 46-8) has observed, two possible implications of this development: Mode 2 knowledge could either 'replace' or 'supplement' science as the dominant mode of knowledge production. The reason either outcome may occur is, as Gibbons and colleagues acknowledge, the emergence of a new market-based economic rationality that acts as a

principal filter to ensure that public and private sources of funding for research are equally concerned with identifying tangible benefits, for example, the production of Covid vaccines: - a development that results in a concern on behalf of funders to involve stakeholder communities in the production and verification of Mode 2 knowledge, and to justify the benefits of such knowledge production to user communities. In a later work Gibbons and some of his original colleagues present a much more overt sociological conclusion. They argue that the ongoing development of Mode 2 is resulting in the emergence of 'Mode 2 society' (Nowotny *et al*. 2002: 47-8). This new type of society is evolving as a result of economies and societies 'co-evolving' alongside one another because they are now subject to similar driving forces, for example, addressing 'risks' (Beck 1992), and therefore jointly concerned with extracting the material benefits from transdisciplinary knowledge.

Critique of professional-scientific knowledge

Contemporaneous to Schön's critique of technical rationality, doubts were already being expressed in Western societies about the idea of objective universal criteria of truth, including the idea that membership in extra-territorial professional fields automatically guaranteed the applicability of professional judgements. This development is discussed very insightfully by Bauman in *Legislators and Interpreters* (1987). The book's premise is that Western societies since the Enlightenment had operated with a conception of intellectuals as 'legislators', that is, offering explanations of events that were simultaneously a 'tool of prediction' and under certain circumstances 'control' (Bauman 1987: 3). From this perspective, intellectual legitimacy depended on the adequacy of knowledge about different states of affairs, for example, engineering, medical, scientific, and such knowledge was firstly, 'attainable from the laboratory experiment or societal practice' (Bauman 1987: 3-4). Secondly, it supplied criteria to classify potential courses of social action as superior or inferior to one another, and this is possible because the objectivity of the judgement is publicly testable and demonstrable. According to Bauman (1987: 4), this rationale has underpinned a view that certain occupations had an epistemological basis to their work and, therefore, could be classified as professions, and that the role of the professional was to 'legislate because they were able to make authoritative statements which arbitrate in controversies of opinions and which select those opinions which, having been selected, become correct and binding.' The basis of these statements being the procedural rules professionals had acquired through studying a discipline in a university and the professional translation of those disciplines through apprenticeship in a field of practice.

The inspiration for the unravelling of the status of intellectuals and professionals came, according to Bauman (1987: 110), from the arguments expressed by various writers associated with postmodernism. They challenged the grand narrative, which had existed since the Enlightenment, that scientific knowledge constituted the quintessential building block of modernity by drawing attention to, on the one hand, the ideological basis of the relationship between knowledge and power and on the other hand, the 'wicked problems' that modernity was generating, for example, environmental crises etc. for which science was not generating solutions. Taken together, these developments had resulted, according to Bauman (1987: 117-22), in a profound change in the status and role of intellectuals and professionals; their new role vis-à-vis the public had become to act as an 'interpreter' who translates 'statements made within one community-based tradition, so that they can be understood within the system of knowledge based on the other tradition' to facilitate communication between professional and lay participants (Bauman 1987: 5).

In making this case, Bauman (1987) points out that this shift from legislator to interpreter does not eliminate the concept of professional scientific knowledge, because the critique cannot be conceived without it. It does, however, entail the abandonment of the universalistic ambitions of professions to provide unchallengeable objective knowledge; however, this, in turn, does not entail an abandonment of professionals' universalistic ambitions towards their own tradition. They still retain their meta-professional authority in this context. The professions therefore face, according to Bauman (1987: 117-22), a two-fold dilemma: to learn how to operate within the boundaries of their community in accordance with its legislative practices; and, to translate their disciplinary-based insights to other professionals and/or their clients so they can grasp the meaning of those insights and infer how to respond to them.

A further return to the missing conversation

The shift in the role of the professional from legislator to interpreter allows us to revisit from a very different angle not only Schön's epistemology of practice and Young and Muller's trinary, but also the new modes of and sites for the production of knowledge. While there may well be a reflective dimension in the new role of the professional to translate disciplinary-based insights to professionals in the same and other fields of professional practice as well as lay communities, the concept of reflective practice is, in principle, a conversation-with-self about one's own actions, the knowledge drawn on, and reasons for doing so. The issue of communication with others, including translating one's professional insights so they are intelligible to other professionals, lay communities etc. falls outside the

immediate provenance of reflective practice and, by and large, a reflective practicum. This is because Schön conceived of a reflective practicum as a mechanism to introduce, what can be referred to as, profession-specific maxims into professional education. The claim that one part of professional-scientific knowledge is to know how to explain the judgement that underpins a maxim calls for a rethinking of the concept of a reflective practicum: an issue warranting further consideration.

Equally, the tension Bauman identifies that underpins professionals' legislator and interpreter roles is completely absent and unacknowledged in Young and Muller's trinary. The overriding impression conveyed by their discussion of regions is that they are legitimate and unproblematic, because the knowledge they provide about engineering, medical issues etc. has been scientifically verified through trusted methods, and that the objectivity of professionals' judgement can be publicly tested and demonstrated. Bauman allows us to appreciate, however, that although professionals do not have to abandon their universalistic ambitions towards their own tradition, it is nevertheless incumbent on them to recognize that the knowledge associated with their profession does not *itself* guarantee the objectivity of their decisions and judgements because that knowledge has been applied contextually. The performative role of professional scientific knowledge and the communicative role of professional work is, however, acknowledged explicitly in discussions about new modes of, and sites for, knowledge production. Nevertheless, the broad thrust of Bauman's nuanced observations about the traditional professional-scientific conception of knowledge applies equally to transdisciplinary modes of knowledge production. Arguments about the performativity of all knowledge, on the one hand, further problematize the traditional conception of professional scientific knowledge; however, on the other hand, this does not entail that professionals completely abandon their universalistic ambitions, rather, it offers further substance to the claim advanced in this chapter that they are a particular kind of contextual accomplishment.

Consequences of the scientificization of society and the socialization of science for professional-scientific knowledge

What emerges from the above discussion of new modes of production of knowledge is firstly, a spectrum of three conceptions of knowledge, consisting of disciplinary (singular), interdisciplinary (region) and transdisciplinary, including research-partnership or firm-based knowledge. The unifying thread between each conception is that they are all contextual. Each one is characterized by a mediated relationship between their mode of

production, relationship to practice, standards of verification and measures of performativity. This mediated relationship ensures, as we shall see below, that each conception of knowledge is supra-contextual, in other words, susceptible to recontextualization, rather than being context bound. These conceptions and their key features are present below in Figure 1.

Figure 1. Spectrum of knowledge

Conception	Disciplinary	Inter-disciplinary	Transdisciplinary, inclu research-partnership/firm (R-p &/or F-b)
Mode of production	produced by members of disciplinary teams	produced by members of interdisciplinary team	produced by member of R-p teams
Relationship to practice	internal to a discipline	internal to inter-discipline & external to professions drawing on that inter-discipline	internal to transdisciplinary t external to stakeholders, inc inter-disciplines represent transdisciplinary team
Standard of verification	discipline generated	inter-discipline generated	context of application gene
Performativity	discipline determined	inter-discipline & profession determined	transdisciplinary team & stakeholder determine

Disciplinary and interdisciplinary knowledge are, as Young and Muller noted, produced, codified and verified in accordance with longstanding protocols, conventions and methods of inquiry associated with their respective knowledge structures. The former's relationship to practice is internal; in other words, it is produced and verified and its performativity (i.e. impact in the discipline) determined by members of the discipline, for example, physics. The latter's relationship to practice is internal and external. Interdisciplinary knowledge is initially produced and verified and its performativity (i.e. impact in its inter-discipline) determined by specialisms within the overarching inter-discipline, for example, electrical or mechanical engineering, and that knowledge is subsequently verified and its performativity determined by members of professional fields, such as electrical and mechanical who have an interest in the professional-scientific knowledge that inter-discipline has produced. The situation for research-partnership based and firm-based transdisciplinary knowledge follows a similar, though slightly more contingent, logic and pathway. They are produced, codified, verified and their performativity judged in accordance with protocols, conventions and methods of inquiry established by the members of a transdisciplinary team. They are also subject to further verification as their performativity is judged in the market.

Secondly, a case to justify the inclusion of both research-partnership

and firm-based transdisciplinary knowledge as elements of professional-scientific knowledge and hence professional-scientific curricula. A slightly different case, however, has to be advanced to justify the inclusion of both as elements of professional-scientific knowledge. Transdisciplinary knowledge produced through research-partnerships involving industry and university departments is a circular mode of knowledge production, because it can be fed back into an inter-discipline and can trigger further developments within it (e.g. Open Source Software and Computer Science). Consequently, this mode of professional-scientific knowledge constitutes what can be referred to as a workplace-generated axiom, which can serve as a new, though not necessarily dominant, element of an interdisciplinary curriculum. In contrast, the transdisciplinary knowledge produced through firm-based activity constitutes a paradigmatic example of team-produced maxims; in other words, it emerges from the way in which professionals from different specialisms (see earlier public library example) comingle their theoretical knowledge and practical experience to create new knowledge in workplaces. This mode of professional-scientific knowledge is therefore, potentially, study material for inclusion in interdisciplinary curricula as an illustration of the type of inter-professionally generated knowledge.

These conclusions, however, take us back to a prior observation that the mediated relationship between each conception and their mode of production, relationship to practice, standards of verification and measures of performativity ensures they are susceptible to being recontextualized in different ways. To understand why this is the case, it is necessary to explain, briefly, the concept of recontextualization.

Professional-scientific knowledge as continuous recontextualization

The origin of this concept lies in Cultural-historical Activity Theory – a tradition that has long recognized the contextual, but not context bound, nature of knowledge, practice and tools (see e.g. Cole 1998 for an overview) – enriched with insights from complementary theoretical traditions (Guile 2010; 2019). The concept is underpinned by three assumptions. The first is that the 'purpose of an activity' influences the way in which any resource is deployed. In the case of curricula, the parties involved select theoretical concepts from contexts, such as disciplinary texts and/or research papers, for inclusion, and then use the aim of the module, in conjunction with the degree of complexity of the theoretical concept, to determine how to sequence it in a module. The second is that all contexts, though in ways that reflect their purpose and content, are underpinned by a 'web of reasons', in other words,

normative assumptions, practices and conventions. These offer the basis of the intelligibility and communicability of the concept, tools and practices among members of that web, as well as to members of other webs of reasons, for example, module teams, workplace project teams etc. The third is that all activities and their contexts are, in principle, problem spaces where people are positioned to work with one another by engaging in the 'social practice of giving and asking for reasons' and inferring what follows from their conversations, debates, deliberations etc. as regards the maintenance or development of that problem space (Guile 2014: 80-82). The knowledge-practice-relationship in problem spaces is therefore normative; the critical issue is that this normativity is a situational accomplishment rather than a result of the knowledge professionals have acquired through study. Recontextualization is therefore an 'open' (Guile 2019) concept that can be evolved to take account of new developments within, and between, traditions, including the creation of new cultural tools and constituencies of interest.

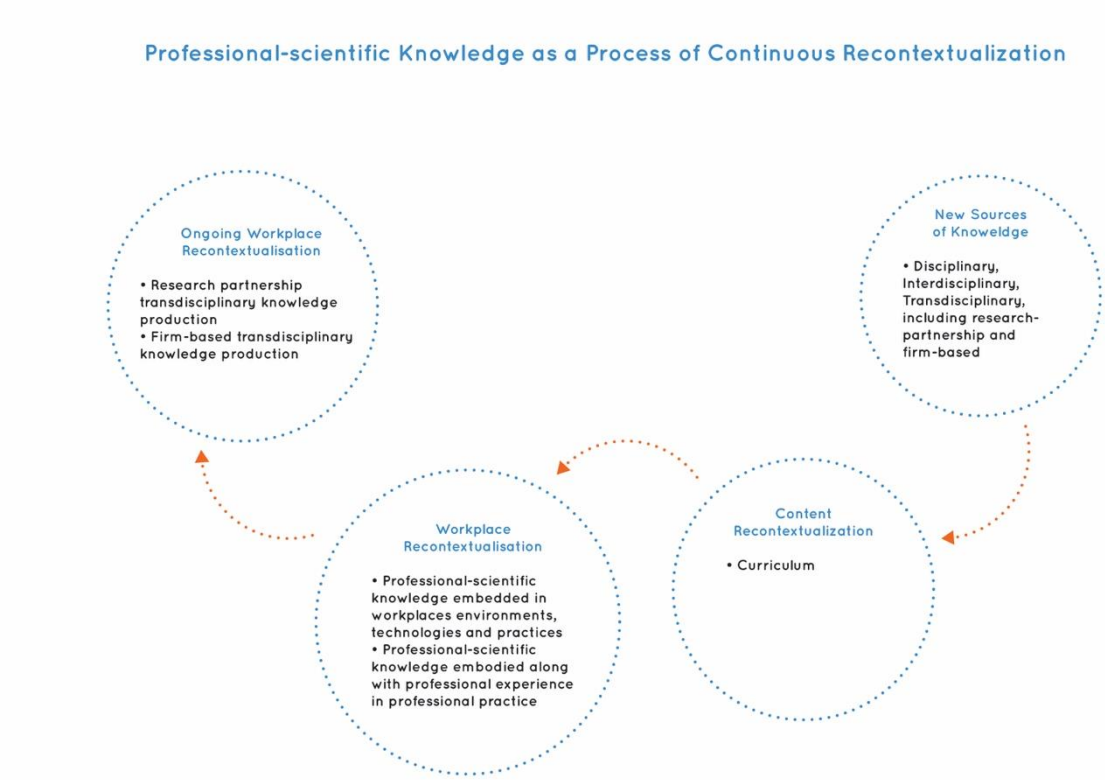
Before explaining how interdisciplinary and transdisciplinary knowledge curricula are created through a process of recontextualization and, as such, can be further recontextualized in professional education curricula and in workplace practice, it is important to clarify affinities, and differences, between my use of the concept of recontextualization compared with Young and Muller's usage of the same term.

Like Young and Muller, I accept that interdisciplinary knowledge is initially created through the recontextualization of singulars into regions, and that the subsequent movement of theoretical knowledge from its region into a curriculum context enables it to become teachable. Where the difference between their and my use of the concept of recontextualization emerges is with respect to a number of conceptual issues. The first is that Young and Muller follow Bernstein and conceive of recontextualization, even if it involves selection, appropriation and refocusing, as a linear process from research via discipline to curriculum. In contrast, I conceive of recontextualization as a multi-faceted and unidirectional process where theoretical knowledge moves into curricula and become embedded in work artefacts and embodied in work process as well as moving from the latter back into the curriculum. This allows me to embrace and supplement Young and Muller's conception in a number of ways. My conceptualization enables us to see how knowledge produced outside traditional research environments, in other words, transdisciplinary knowledge, is not only produced through a process of recontextualization, but also can be dis-embedded from its context of production and recontextualized as an element of an inter-disciplinary curriculum. This is possible because transdisciplinary knowledge's multi-faceted knowledge structure allows it to be related to the specialisms involved in its production. Furthermore, as a consequence of being included as part of a region, transdisciplinary knowledge can either spur further

research and innovation in that region or become a new region itself.

The other issue is that Young and Muller, as Bernsteinian-influenced curriculum theorists, are inclined to follow him and treat knowledge structures in fairly deterministic terms. This leads them to imply that the hierarchy of concepts in a discipline/inter-discipline should exercise a powerful influence on the way in which concepts are recontextualized, in other words, sequenced in a curriculum, that students learn concepts and then when they become professionals 'apply' those concepts to practice. In contrast, my CHAT-informed conception of recontextualization allows, firstly, the embedded nature of theoretical knowledge to become visible by revealing that theoretical knowledge, along with other forms of knowledge, for example, legal, firm-based transdisciplinary etc., is embedded in workplace environments both technological as well as work routines and practices. Consequently, the challenge for professionals is to learn firstly how to take account of different forms of knowledge, which may not emanate from their specialism, when they are working with others to determine appropriate courses of action in workplaces. Secondly, that as they commingle their specialist knowledge in conjunction with the diversity of their practical experience (in other words, working on canonical or non-canonical problems in profession-specific or interprofessional teams), they develop their own form of knowing (see e.g. Guile 2011(a)(b) and 2018).

The above argument is represented visually in Figure 1 below. It illustrates that professional-scientific knowledge is best viewed as a process of continuous recontextualization because there has always been a reciprocal relationship between different forms of knowledge and the contexts in which they are located. As such, the gap between theory and practice that exercised Schön and Young and Muller is a product of the legacy of binary thinking in their respective formulations of knowledge and its relationship to context, rather than the existence of an actual gap between different contexts and modes of knowledge.



In making this argument, I am not undervaluing the various challenges associated with, for example, recontextualizing singulars as regions or aspects of regions, in conjunction with workplace technology, as transdisciplinary knowledge. Instead, I have shown that once we conceive of professional-scientific knowledge as a process of continuous recontextualization we can embrace not only extant modes, but also emerging modes, of knowledge production.

To illustrate this claim, I discuss, briefly, the challenge that Machine Learning (ML) poses to knowledge production and by extension professional-scientific knowledge. ML is a sub-field in Artificial Intelligence that is being developed via research-partnerships and firm-based activity (Russell and Norvig 2016). ML is predicated on the interfacing of human-generated data, for example, medical, with an algorithm that has a capacity to 'learn' by itself (see *e.g.* Alpaydin 2016, Domingos 2015, Royal Society

2017); in other words, an algorithm detects patterns in data that are otherwise undetectable to human eyes and generates conclusions for professionals to consider before acting on (see *e.g.* https: //www.theguardian.com/commentisfree/2020/dec/06/the-guardian-view-on-deepminds-brain-the-shape-of-things-to-come and https: //www.theguardian.com/business/2021/feb/20/drug-companies-look-to-ai-to-end-hit-and-miss-research). The type of knowledge produced by ML can, to borrow Knorr Cetina's term (2010), be defined as 'information knowledge', that is, knowledge produced by an algorithm, rather than in accordance with the classic scientific or transdisciplinary method, that is nonetheless a contribution to an extant field of professional-scientific knowledge. The process – data and algorithm – as well as the outcome of ML – information-knowledge – can be viewed as not only a new example of continuous recontextualization (Guile forthcoming) and hence constituting a new manifestation of the relationship between theory and practice, but also as a development introducing a new performative challenge: the extent to which ML's decision-making process is 'explainable' and by extension trustworthy (Meske *et al*. forthcoming).

Conclusion

The aim of the chapter was to rethink the concept of knowledge in professional-scientific education to take account of both current conceptions of that form of knowledge as well as ongoing scientificization of society and the socialization of science which has resulted, and continues to result, in new modes of knowledge production. To do so, the chapter started by using the different positions about knowledge represented by Schön and Young and Muller to highlight the insights and oversights associated with the legacy of binary thinking about the relationship between knowledge and practice. It then deepened this line of argument by setting up a missing conversation between Schön and Young and Muller's respective positions in the following way. It discussed how firstly new modes of knowledge production (Gibbons *et al*. 1994) and new sites for the production of knowledge (Nonaka and Takeuchi 1995) have broadened what should be included in the concept of profession-scientific knowledge. Secondly, the transition from modernity to post-modernity has introduced a more explicit *performative* dimension to the status and role of knowledge in societies (Bauman 1987). The chapter argued that the unifying thread between the above developments is that they have drawn attention to the contextual, rather than context-free, basis of professional-scientific knowledge, and exemplified this development with a conception of a knowledge spectrum that encompassed disciplinary,

interdisciplinary and transdisciplinary knowledge, including its research- and company-based expressions. The chapter then explored the implications of this spectrum through reference to the concept of recontextualization that explicitly acknowledges the mediated relationship between knowledge, practice and context (Guile 2010; 2019). It concluded by demonstrating that: (i) all three forms of knowledge are created by and developed within different contexts through a process of the *continuous recontextualization of knowledge and practice*; and (ii) there is a reciprocal relationship rather than a gap between forms of knowledge, practice and context. The chapter concluded by exploring the implication of these issues with respect to machine learning.

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