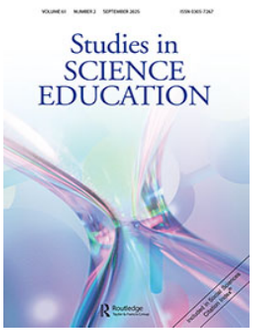

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Introducing sociopolitical approaches to science education: an integrative review of the concept of subjectivity in science curricula and continuous professional development programmes

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ABSTRACT

Drawing on the sociopolitical turn within science education, we critically examine subjectivity production in curriculum developments and Continuous Professional Development (CPD) programmes. Through a review of 178 outputs, we identify three themes: (a) subjectivity meanings in science, sociological perspectives, and science education; (b) sociopolitical questioning in science education and the curriculum; and (c) challenges to CPD programmes, where the challenges are sensitive to issues of power imbalances. This integrative review maps critical approaches and debates, problematising science curricula and CPD programmes. We discuss curriculum development, teachers' participation, and the role of teacher educators and universities in CPD programmes. We show how curriculum developers are typically positioned as the thinkers who 'wish' to improve the quality of science learning in schools with their ideas, while schoolteachers are seen as simply the implementers of those thoughts. We offer directions on the sociopolitical turn using subjectivity, questioning assumed norms through social, political, and cultural lenses within school science education. For any teacher educator conducting CPD programmes, the sociopolitical approach could help shape the reconceptualisation of such programmes by incorporating power-sensitive questioning about such issues as the way that the CPD is designed and conducted, and the professional development of the teacher educators themselves.

KEYWORDS

Sociopolitical turn; science education; subjectivity; science curriculum; continuous professional development (CPD) programmes

Introduction

There has been a recurrent 'call' for more explicit and collective engagement between science education and the sociopolitical dimension (Carter, 2014; W. M. Roth, 2008; Tolbert & Bazzul, 2017), in acknowledgement of the limited study of political discourses within the field (Pedretti & Nazir, 2011). This is commonly referred to as the 'sociopolitical turn' in science education, by which is meant an acknowledgement that science

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education is not value-neutral and that therefore researchers need to take account of culture and power structures. Indeed, the call to bring the political nature of science to the spotlight has been made for some time by philosophers of science (Lather, 2012), feminist critiques of science (Stefanidou & Skordoulis, 2014), and those working in cultural studies using postcolonial theory in science education (Carter, 2004, 2008) amongst others. Similarly, there have been efforts to intersect social justice with the nature of science and pedagogical content knowledge to put social justice at the heart of the school science curriculum (Levinson, 2018). There has also been broader understanding of the nature of science, including the social-institutional, political, and economic dimensions of science (Gandolfi, 2021, 2024). Nevertheless, there are still narrow views of science and science education that cannot continue if the field wants to respond positively to contemporary movements towards critical and cultural studies (Lather, 2012), in a changing world (Adams et al., 2018), towards just futures (Torres Olave, 2024).

Why is this important? Carter (2014) stated that the theorisation of this political dimension in science education, by exposing, for example, neoliberalism in its discourse, could open the door for 'better' science education; it could also help identify potential sites 'of/for resistance to neoliberalism' (Williams & Tolbert, 2021, p. 71). Such a response may also help resolve the sense of disaffection that students have about the (lack of) relationship between school science and their lived experiences (Levinson, 2018). The starting point of this more explicit call recognises that while there is extensive research within science education, there is less research that includes a sociopolitical dimension, meaning that science education too often remains 'thin' (Bazzul, 2012). In other words, the sociopolitical turn calls for transgressing/trespassing boundaries (Pereira, 2019), troubling the hermeticism in science education that has typically led to science education avoiding examining itself through the lenses of social, critical, or philosophical theories (Kayumova, 2015).

This sociopolitical turn in science education has been chiefly theorised from current social, economic, and political struggles. Latin American scholars, notably Freire, are well-known in general education for their advocacy of critical pedagogies and articulation of possibilities for resistance to the pervasive hegemony of education's neoliberal foundations; however, they are less explored in science education (Carter, 2014; Tolbert & Bazzul, 2017). Therefore, as the aim of the turn is to question the missing explicit awareness of the sociopolitical within the field of science education (Pereira, 2019), we use the sociopolitical turn as a stance to understand aspects, such as the production of subjectivities, power relationships, hierarchies, and control of curriculum development, that could be influencing experiences around Continuous Professional Development (CPD) programmes. *We therefore critically examine subjectivity in curriculum developments and CPD programmes through a sociopolitical lens*. This is our key focus – the various topics we include are included to serve this overall purpose. We are guided by the following three arguments. First, the sociopolitical turn is a call to break the impenetrability of science education by drawing on notions/questions/methods from other fields to interrogate the science education field. This call has been mostly theoretically based with some empirical examples (i.e. examples that have gathered and analysed actual data) using the notion of subjectivity. A conceptualisation of subjectivity, understood as the everyday relations that articulate how experience is lived in relation to a specific institutional context, highlights the socially situated understanding of subjectivity, wherein the encounter with 'other'

(whether the social structure, language or an-other) could be what produces subjectivity, and could bring a broader understanding to science education research by adding the socially situated understanding of the term. Secondly, the science curriculum has many aims that are often presumed to hold universally, which raises the question of its situatedness and how, for example, it deals with issues of power and knowledge in different societies. In terms of curriculum development, schoolteachers are usually treated as implementers, executors, or information providers, and only rarely as developers. Thirdly, a common policy concerning curriculum changes consists of using professional development programmes delivered by universities, creating a hierarchical relationship. Often, the role of the teacher educator is conceptualised as giving schoolteachers the necessary support to guarantee that the curriculum and its changes are 'implemented appropriately'. The professional development of teacher educators is omitted because the focus is on developing the schoolteachers' knowledge and practice. The university as an institution is unquestioned in the CPD space. Therefore, to unpack and think critically about the subjectivities produced in CPD programmes in science education should allow us to explore: hierarchical relationships between the university and the school; the control and colonisations of curriculum changes; the omitted professional development of teacher educators; and the influence of institutional context on, for example, the participants of the CPD programmes. By asking after and looking back at the conditions of that subject formation, we – science teacher educators, colleagues – could keep interrogating what is assumed to be the state of things by asking social, political, and culturally relevant questions, situating these within the context of school science education.

Our review takes up a particular portion of this examination, focusing on one area of science education as science educators ourselves; specifically, this review is the result of the doctoral process of the first author alongside one of her PhD's supervisors as the second author. Based on the extant literature, we attempt to answer the following questions:

> What does it mean to research subjectivities in science education? To what extent can the sociopolitical lens be applied to the subject formation in curriculum development and teacher education?

To respond to these questions, we extensively searched and analysed the literature. First, we engage with a central concept of the sociopolitical turn, namely subjectivity, and examine how the turn is being addressed (through both empirical and theoretical approaches). Secondly, we explore literature about curriculum development in science education. Thirdly, we explore literature in science education related to CPD programmes, problematising the role of universities and teacher educators in them. Fourthly, we examine the positionality of the sociopolitical approach. Finally, we conclude by highlighting gaps and potential contributions to researching subjectivities in science education, specifically in curriculum development and teacher education.

A recent editorial in *Review of Educational Research* encourages authors of reviews to provide positionality statements and 'to make their entry point into research inquiry explicit' (Boveda et al., 2023, p. 3). Paulina is a cis female, Latinx academic who comes from a working-class background and is in love with insects and, recently, in love with dogs. She is a biologist, with a master's degree in science education from a Chilean university and a PhD in science education from a university in London. Although her

initial training was in biology, her recent work shifted her passion from insects to people, moving from the natural to the social sciences. Now, her work is mostly related to teaching at the doctoral level at a university in Chile. Michael is a cis male, white academic who comes from a middle-class background and always wanted to be either a scientist or a schoolteacher. After a PhD and post-doc in evolutionary biology and population genetics at the University of Cambridge, he trained to be a schoolteacher and then taught in the state school system in England for five years. He then spent six years running initial teacher education courses for trainee secondary science teachers and then six years running initial teacher education courses for trainee primary teachers of science, before taking up his present post in 2001. Most of his teaching is now at doctoral level.

Methods

Literature search and selection

The literature review process drew on our familiarity with science education, curriculum development and CPD programmes. On the one hand, the literature review of the science education dimension was undertaken through an intentional process with a purposive sample (Randolph, 2009), selecting peer-reviewed articles, books, doctoral theses, and government reports in the field. Those documents were searched using the University College London 'Explore' engine, which has extensive physical and digital catalogues including, among others, Education Resource Information Centre (ERIC), OECD Library, SCOPUS, and Web of Science. The keywords searched were 'science education', 'curriculum', 'science education curriculum', 'continuous professional development', and 'CPD and science education', restricting the search to the 1990–2022 period. A comparable search was conducted with open-access Latin American databases such as SciELO, Latindex, Catálogo, and Redalyc for the period between 1990 and 2020. We conducted this part of the literature review related to our familiarity with the science education field, which is closer than the sociopolitical dimension to our disciplinary backgrounds. Abstracts identified from the search were read by the first author and decisions made regarding whether or not to exclude the publication from further consideration. All outputs not excluded were then read by the first author, and decisions were made as to whether or not to exclude the publication from the review. When the first author was unsure whether or not to include a publication, this issue was discussed with the second author. In the end, we included 178 outputs. Table 1 lists these 178 outputs by theme. This is an integrative review, so we make no claim that our review has met the formal tenets of a systematic review. Rather, an integrative review synthesises and evaluates current knowledge of a topic, so as to produce new insights (Cronin & George, 2023). Such a review is therefore particularly appropriate when the intention is to bring together scattered literatures and suggest new directions for a field.

In our literature review of the sociopolitical dimension, we do not claim to have been 'objective' (cf. Randolph, 2009). We proceed much as Henderson (2015) did when she writes that she 'felt my way through' (p. 53) some citation trails, authors, recommendations, and personal conversations specifically related to the topic at hand. In writing about what we concluded, we attempt to show both our excitement and our confusion on reading this body of literature – previously known only partially to us – that resonated

Table 1. Lists of references per theme.

Subjectivity meanings in science, sociological perspectives, and science education	Sociopolitical questioning associated with science education and the science curriculum	Challenges to CPD programs under power-sensitive questions
Alsop and Bencze (2014)	Abrahams (2011)	T. Acuña et al. (2016)
Amigot and Martínez (2013)	Hollins and Reiss (2016)	Aldahmash et al. (2019)
Avraamidou (2020)	F. Acuña (2020)	Amponsah et al. (2021)
Ball (2003)	Aikenhead (2005)	Ávalos (2002)
Bazzul (2012)	Albashiry et al. (2015)	Bakx et al. (2016)
Bazzul (2016)	Ayala-Villamil (2019)	Bell (1998)
Bazzul and Siatras (2011)	Bantwini (2010)	Bell and Gilbert (2005)
Bazzul and Tolbert (2019)	Bencze (2017)	Blackmore and Kandiko (2011)
Bazzul et al. (2018)	Bencze and Hodson (1999)	Cavieres and Apple (2016)
Bazzul et al. (2019)	Bencze and Hodson (1999)	Chou (2011)
Bencze and Carter (2011)	Bradley and Moodie (2017)	Chval et al. (2008)
Brandt and Carlone (2012)	Bravo et al. (2019)	Clarke and Hollingsworth (2002)
Bunge (1995)	Calsado (2020)	Cochran-Smith et al. (2019)
Butler (1992)	Carter (2016)	Day (1999)
Butler (1997)	Chacón (2016)	Eilks and Markic (2011)
Butler (2005)	Couso (2016)	Freire (2002)
Butler and Athanasiou (2017)	DeBoer (1991)	Geldenhuys and Oosthuizen (2015)
Louis and Calabrese-Barton (2002)	Dillon and Avraamidou (2020)	González-Weil et al. (2014)
Cannizzo (2018)	DuFour (2007)	Guerrero & Reiss (2020)
Carter (2014)	Freeman et al. (2015)	Guskey (2003)
Curtis (2012)	González (2015)	Hargreaves and O'Connor (2018)
Harvey (2007)	Higgins et al. (2018)	Herbert and Rainford (2014)
Fardella (2020)	Hökkä et al. (2010)	Hooks (1996)
Fifield and Letts (2014)	Holbrook and Rannikmae (2009)	Kafyulilo (2013)
Foucault (1988)	Hollins and Reiss (2016)	Kurtén and Henriksson (2021)
Foucault (1997)	Jenkins (2020)	Lefstein and Snell (2013)
Freire (1970)	Jiménez (2010)	Lessing and De Witt (2007)
Gill (2009)	Marks and Eilks (2009)	Lieberman (1996)
Gunton et al. (2022)	Martín-Páez et al. (2019)	Loughran (2007)
Haraway (1988)	McKinley and Stewart (2012)	Loughran and Menter (2019)
Harding (1991)	Millar and Osborne (1998)	Lumpe (2007)
Heyes (2010)	I. Mitchell et al. (2017)	Luneta (2012)
Higgins et al. (2018)	Morin et al. (2014)	Martins-Loução et al. (2020)
Hodson (2003)	Morin et al. (2014)	Mena et al. (2017)
Kayumova (2015)	Ogborn (2002)	R. Mitchell (2013)
Kincheloe and Tobin (2015)	Osborne (2007)	I. Mitchell and Mitchell (2008)
Lagos-Serrano (2021)	Osborne and Dillon (2008)	Núñez et al. (2012)
Lather (2012)	PRETeC (2018)	OECD (2005)
Layton (2008)	Morin et al. (2014)	Parejas and Margalef (2013)
Moje (1997)	Ryder and Banner (2013)	PRETeC (2018)
Montenegro (2016)	Saracaloğlu et al. (2010)	Shulman and Sherin (2004)
Pereira (2019)	Sikorski and Hammer (2017)	Simon and Campbell (2012)
Phillips (2011)	J. Smith and Girod (2003)	K. Smith (2003)
Ratner (2002)	Stuckey et al. (2013)	K. Smith and Loughran (2017)
Rodriguez (2019)	Torres et al. (2019)	Stoll and Louis (2007)
W. M. Roth (2008)	Tovar-Rodríguez (2019)	Stoll (2020)
W. Roth (2009)	Van Driel et al. (2001)	Subitha (2018)
Santos (2009)	Vieira and Tenreiro (2016)	Thody (2008)
Smuts (2006)	M. F. Wallace (2018)	Tippins et al. (1993)
Thomas and Vavrus (2019)	M. F. Wallace (2018)	Torres-Olave and Bravo (2021)
Torres-Olave (2021)	Yeh et al. (2019)	Tsui and Law (2007)
Van der Klink et al. (2017)		Uçan (2016)
Vanderlinde et al. (2021)		Vaillant (2019)
B. A. Wallace (2004)		Vaillant and Cardozo (2016)
M. F. Wallace (2019)		Van Driel et al. (2012)
Walsh (2013)		Wallace and Loughran (2003)
Weaver (2018)		Wenger (2000)
Zemelman (1997)		

with the analysis while also problematising our familiar understanding. Finding this literature entailed an element of serendipity, which evoked the point of intersection between science education and its sociopolitical dimension as the contribution of this proposal by mapping an assemblage between the two in a way that allows us to build this integrative review.

A brief contextualisation: critical concepts of the sociopolitical turn

There are two key aspects of the sociopolitical turn that are particularly relevant here. The first is related to the transgression of boundaries between fields (e.g. Pereira, 2019) by bringing attention to notions such as subjectivity. The second goes further, attempting to understand the subjectivation process/subject formation by exploring power-sensitive questions (i.e., questions that respond to potential power imbalances between actors) and unpacking social and political aspects of that production (Kayumova, 2015) in curriculum development and teacher education. Pereira (2019) sees the transgression of boundaries between fields – 'boundary work' – as an ongoing process of 'demarcation, negotiation, and disruption' of the borders between science education and other fields (p. 359). In *re*examining these roles and *re*thinking the benefits of using theories from other fields, fixed claims in science education can be both challenged and *re*conceptualised, promoting a more nuanced understanding, where science is situated in social, historical, and political power relations (Kayumova, 2015). The question of subjectivity in science education concerns the 'call' to pay attention to sociopolitical discourses rarely studied within the field and to entertain the possibility of transgressing boundaries between disciplines.

Results

We argue that the articulation between subject formation in curriculum developments and teacher education, especially CPD programmes, is related to create a point of intersection between the sociopolitical lens and the science education field. This helped us to problematise, for example, the sociopolitical dimension in our practices as teacher educators, the practices of our colleagues and the way we conceptualise CPD programmes in science education, as well as curriculum development and changes in the science curriculum. In so doing, we explore what science education is, and the potentialities of 'what may also be, but not yet is' (Moura, 2021, p. 1). Here, we can see the heart of this questioning, in relation to unpacking the power relationships that are part of the sociopolitical context, and understanding teaching and learning in the curriculum and in teacher professional development courses. Thus, as the notion of subjectivity is key to developing our argument, we provide a layered account of different conceptualisations of the term.

Subjectivity in science

There is a debate as to how subjectivity has been understood in science. The standard perspective is that subjectivity is understood as opposed to objectivity, which is seen as the way to access what is supposedly 'real' and 'true' (Ratner, 2002); subjectivity is

therefore seen as a 'bias' of the researcher who is unable to stand entirely outside of their particular perspective. Conversely, another perspective recognises objectivity as an important yet problematic concept (Gunton et al., 2022), attempting its reconceptualisation by including the researcher in the same critical plane as the research project, where both are socially situated (Harding, 1991).

There is therefore a shared conception of subjectivity in science, which is in tension with objectivity, where the subject undertaking the research stands outside what is studied. Smuts (2006) stated that '[i]n Western culture, the "objective" and "subjective" perspectives are viewed as different and competing approaches to determining what is real' (p. 116). Smuts draws on the writing of C. P. Snow, who in 1959 described the tension between 'objective (science) and subjective (literature, art, etc.) approaches to scholarship'. The objectivity-subjectivity tension in science can be found in later works. Mario Bunge[1] – who positioned himself as a realist materialist – stated that there is a scientific method which includes 'always to measure and to register the phenomena' from the outside world as a key feature of the factual sciences (1995, p. 14). Bunge described how by some other elements of doing science, like observation and experimentation where scientists should not consider their own experience as a plausible factor, scientific knowledge is always clear and precise, controlling variables is of the utmost importance, and scientific knowledge is generalisable and universal. Along the same lines, Scheffler (1982) in his book *Science and Subjectivity* stated that the purpose of that work was to defend objectivity, so needed in science because otherwise 'there can be no science' (p. vii). In Scheffler's words, science should have 'devices of control' (p. 2) to promote the scientific attitude of impartiality and detachment, in order to 'limit' subjectivity, which, according to B. A. Wallace (2004), could taint scientific observations. Curtis (2012) stated that '[w]hile the evidence-based approach of science is lauded for introducing objectivity to processes of investigation, the role of subjectivity in science is less highlighted in scientific literature' (p. 95). Even though Curtis makes a point of the importance in considering the subjectivity of the researcher, the way Curtis conceptualises subjectivity is in relation to biases made by individuals and he finishes the article by calling on geologists and other scientists not to be 'ashamed' of their own subjectivity due to a supposed lack of scientific rigour; instead, he argues 'we [scientists] *should* strive to develop methods to quantify and sometimes to reduce its effects' (italics in the original, p. 96).

The call to reduce the alleged effect of subjectivity is quite contested in other understandings of scientific processes. According to Gunton et al. (2022) '[o]bjectivity as-unbiasedness tells us what objectivity precludes (e.g. bias, idiosyncrasy, perspective, and values), but not, more positively, in what it consists' (p. 2); this offers a way to reconceptualise the notion of bias. Lather (2012) pointed out that '[s]cientists firmly believe that as long as they are not conscious of any bias or political agenda, they are neutral and objective, when in fact they are only unconscious' (p. 1022). In contradistinction to the position of not considering one's own experience, detachment, and reduction of subjectivity, Lather called on researchers to embrace both the limits of their own knowing and the affective response to their research work towards the constitution of a *new scientific subjectivity*, arguably applied to researchers who can challenge the power relation within claims of objectivity of scientific knowledge, understanding that such knowledge is partial and situated within our experience (Haraway, 1988). Kincheloe and

Tobin (2015) gave a similar encouragement to researchers to 'employ reflexive methods to identify the epistemologies, ontologies, and axiologies that are salient in their scholarship' (p. 513), because the very absence of explicating one's position would show one's own obliviousness.

Harding (1991) reconceptualised objectivity – separating it from objectivism – including the subject, to bring together the agent and the object of knowledge for what she called strong objectivity, which 'conceptualizes the value of putting the subject or agent of knowledge in the same critical, causal plane as the object of her or his inquiry' (p. 161). This strong objectivity could be positioned alongside notions of strong reflexivity, which in Harding's words:

> require that the objects of inquiry be conceptualised as gazing back in all their cultural particularity and that the researcher, through theory and methods, stand behind them, gazing back at his own socially situated research project in all its cultural particularity and its relationships to other projects of his culture. (p. 163)

Harding's strong objectivity and strong reflexivity can be seen as a call to take a careful look into cultural particularities (by 'gazing back'), as well as at how research projects are socially situated. In doing so, science can be done ethically where all the voices are taken into consideration; otherwise, it can become a sort of 'scientism favouring powerful voices in the world' (Weaver, 2018, p. 131). At this point, the notion of subjectivity in science as something that is not to be reduced but rather taken into consideration meets sociological perspectives in relation to teachers' subjectivity.

Subjectivity from sociological perspectives applied to teachers' subjectivity

There is a conceptualisation of subjectivity, particularly relevant to this exploration, which highlights the socially situated understanding of the term wherein the encounter with other – whether the social structure, language or another – could be what produces subjectivity; that is, subjectivity emerges in the interplay between individual agency and social structure.

Michel Foucault and Judith Butler are seminal figures in understanding subjectivity (Bazzul, 2012). Foucault (1988) posits that subjectivity arises from a provisional process, shaped within power-knowledge dynamics, allowing for diverse self-conscious organisations (p. 253). Butler (1997) defines subjectivity 'as the lived and imaginary experience of the subject' (p. 122) within historical and political contexts, entangled in discursive power relations (Heyes, 2010; Phillips, 2011). Subjects negotiate their agency amidst competing discourses, with subjectivity neither wholly determined by structures nor reduced to social determinism (Layton, 2008; Zemelman, 1997).

Butler's (1997) conception differs from Foucault's in integrating the unconscious, where subject formation involves both autonomy and subjection to power (p. 83). This paradoxical process requires restrictions for subject production, perpetually iterated rather than instantiated wholly (Butler, 1997). Emphasising subject incoherence and incompleteness challenges fixed identities, suggesting identity cannot be fully captured, echoing notions of encountering Otherness as fundamental to subjectivity (Butler, 2005; Foucault, 1997; Lagos-Serrano, 2021; Layton, 2008). Ultimately, subjectivity entails perpetual rearticulation and negotiation of limits, embracing the potential to transcend

established boundaries (Foucault, 1997). Thus, subjectivity is an ongoing process shaped by encounters with Otherness, social structures, material entities, and linguistic constructs (Lagos-Serrano, 2021; Layton, 2008).

Another kind of subjectivity is posed by Freire and by Ball, specifically in the relation to teachers' subjectivity. In Freire (1970), under the notion of education as a 'banking model', there is a divergent relationship between a teacher-subject who deposits knowledge into an object-student who receives that knowledge. According to Freire, that complex relationship can be shifted by a dialogical pedagogy where there is a reconciliation in the relationship towards both being at the same time teachers and students. In his account of teacher subjectivity in high-stakes accountability educational systems (e.g. schools and universities), Ball (2003) suggests that teachers' responses to control measures leave a plethora of meanings that are permeated with the teachers' everyday life environments. This surplus of the teachers' subjectivity is elusive, due to the impossibility of completely articulating it, which also permeates, in an ambivalent manner, their profession with responses of both resistance and capitulation.

Thus, for Foucault, subjectivity is the formalisation of an experience of self-knowledge, whatever it may be, as one of the possibilities of a self-organisation which results in a subject. For Butler (2005), with the incorporation of the unconscious, there is an incompleteness of the subject which is referred to as 'opacity', where the 'opacity of the subject may be a consequence of its being conceived as a relational being, one whose early and primary relations are not always available to conscious knowledge' (p. 20); thus, there is something in crisis in the subjective experience which could emerge in relation to the other. Now, for Freire, the reconceptualisation of the student positioned as a subject – rather than as an object in the banking model of education – is able then to change their reality because of an effort of '*conscientização*', leaving behind the status of objects while becoming historical subjects (Freire, 1970, p. 170). Here, there is a contrast with Butler, because for Butler, even though it would be interesting to understand the new position in the teacher-student-subject relationship, what is more related to her understanding of the elusive dimension of subjectivity – the above-mentioned opacity – is when the subject experiences some crisis – the fact of becoming a subject while at the same time becoming subjected (Bravo, 2023).

How, then, are these abstract conceptions of subjectivity played out in specific educational institutions? The university – in Chile and also in other parts of the world – as well as other institutions has been increasingly permeated in recent times by a neoliberal business-like logic (Amigot & Martínez, 2013) where there is a transformation of public education to a market-oriented mindset, which produces new subjectivities. The privatisation of the university produces a subjective experience which positions students as consumers while academic staff have seen their remuneration and working conditions deteriorate as the university transforms into 'fast' academia (Gill, 2009). According to Gill (2009), there is a subjectivity of an academia 'always on', available to respond to increasing requirements (p. 9). It has been argued that university workers feel more pressured, to the point of feeling that their working environment is toxic (Cannizzo, 2018). In the case of Chile, Fardella (2020) pointed out the subjectivity of a hyper-agentic academic experiencing the pressure of rankings, productivity indices, and the promotion of competition among colleagues. According to Fardella (ibid.), the relationship between the neoliberal agenda and the subjectivity produced in this scenario is unavoidable. In this context,

there is the subject production of the 'hyper-productive' academic with multiple publications and projects (ibid., p. 2306), which echoes a Foucauldian understanding of subjectivity. Such hyper-productive staff attempt to minimise the influence of their institutional context in favour of maximising their agency, meaning that they do not recognise as overwhelming the university's requirements; rather, they assume the requirements as a personal task. Fardella (ibid.) concluded that there is a satisfaction involved in this hyperproduction that can even disguise the precariousness of these subjects' context.

In the context of the university, there is another subject production that is neglected, namely, teacher educator subjectivity, which has also been neoliberalised. Montenegro (2016) pointed out that the path to becoming a teacher is frequently examined in research, whereas the path to becoming a teacher educator has barely been explored. Furthermore, research on the professional development of teacher educators is a 'relatively young and under-researched area' (Vanderlinde et al., 2021). Montenegro stated that the identity of the teacher educator 'frequently goes unnoticed in the field of teacher education' (ibid., p. 527), even though teacher educators as a group are raising awareness on the process of becoming lifelong learners (Van der Klink et al., 2017). Montenegro (2016) interviewed teacher educators who declared that they had not received support to become such, and that their current knowledge of how to act as a teacher educator was self-made. It is noteworthy that in Montenegro's and Van der Klink et al'.s contributions, they mostly talk about teacher educators when working with undergraduates who are training to become teachers, which leaves more questions regarding the subjectivity of teacher educators in the space of CPD – to which we return below.

The observation of the elusive and paradoxical character of subjectivity and the acknowledgement of its social situatedness may be productive to our exploration of how the subjectivities of schoolteachers and teacher educators are produced and shifted in relation to an institutional context. This productiveness could also help to 'promote multiple "other" becomings'/subjects (Bazzul, 2016, p. 8) or the possibility of 'being from being more' (Freire, 1970, p. 99) by the incorporation of notions from other disciplines – like a sociological perspective to subjectivity – towards addressing the sociopolitical call in the science education field. In what follows, we provide examples of the use of subjectivity in science education to situate the notion in the field.

Subjectivity in science education

The notion of subjectivity in science education meets the sociological perspective of the term, as something that is not to be reduced but rather taken into consideration, including the very acknowledgement of the incoherence and incompleteness of the constant production of the subject. This reconceptualisation resonates with the way in which some science educators have empirically started to use the notion of subjectivity in science education.

Understanding that '[s]cience discourse is not pure, cannot be pure even if it existed in a pure state' (W. M. Roth, 2008, p. 906) allows us to explore how discursive practices in science are shaped by power, institutions, and language, creating a particular experience and perception. In the case of science education, there is a reproduction of dominant discourses of what counts as knowledge and literacy in science. For instance, the work of

Moje (1997) foregrounds the discourses in a chemistry classroom where there was a subjectivity of 'the teacher as expert and producer of knowledge, whereas the students took up positions as consumers and demonstrators of knowledge' (p. 35). Moje states that these discourses are invisible to those who are reproducing them in the classrooms, showing the complexity of discursive practices and, therefore, the complexity of the autonomy of becoming a subject while being subjected to dominant discourses. Here, there is a point of intersection between subjectivity – as socially situated – and science education, where there is a subject production in a particular cultural context that is worth paying attention to. Bazzul (2012) pointed out that understanding the process of subject formation which happens in a particular cultural context (such as the science classroom) brings forth the grounds to reshape how we come to see ourselves and others. In this understanding, educational institutions – e.g. universities and schools – are central to the subjectivation processes of those involved in them, having a role in the *re*production of subjectivity (Bazzul, 2016). The discourses of those institutions might determine how people understand aspects of their identity, such as race or gender, while also validating political orientations and ethical actions.

Drawing on Foucault's theorisation of subjectivity, Bazzul pointed out that '"the subject" is not someone who is necessarily activated by particular truths in discourse but is itself constituted by particular truths in discourse' (Bazzul, 2012, p. 1010). He suggests that the subjective positions we take are produced by possibilities of thinking within discourses where truth and power circulate. Also, drawing on a Butlerian perspective on subjectivity, Bazzul (2012) asserts that Butler's understanding of discourse analysis could be easily connected to, for example, the examination of textbooks in science education by questioning the nature of this subject formation through 'asking after' (Butler, 1997) its constitution. An example of a critical reflection on subjectivity and positionality in science education can be found in Louis and Calabrese-Barton (2002) who – in our view, engaging with Harding's 'gazing back' – recognised issues not previously considered that emerged in their research with parents about science education reforms. What they realised was that there were some intersections between the parents' lives and their own lives, which led them to try to make sense of their own positionality in the research and to question their responsibility to respond either towards the parents and/or academia.

Particularly interesting is the invitation of Lather (2012) to develop a new scientific subjectivity as a way to *re*-'think politics and science anew toward an engaged social science, without certainty, rethinking subjectivity, the unconscious and bodies where we ask "what kind of science for what kind of politics?"' (p. 1021). Building on Lather´s questioning, we would pose a slightly more specific question: 'What kind of science education for what kind of sociopolitical sphere?'. As subjectivities are everchanging in a permanent resignification process, and hence the subject is not a product (Butler, 1992), the question of its constitution – through asking after it and gazing back – in science education would also be unending, trying to uncover what conditions and discourses are producing these subjectivities at the same time as opening a possibility for reworking them (Bazzul, 2016). In our view, the use of such ideas in school or university classrooms gives rise to a question concerning responsibility towards an ethical practice which could contrast with the neoliberal discourses – that are especially prevalent in the Chilean educational system – of these educational institutions (David et al., 2006). Drawing on the above, subjectivity can be understood as the everyday relations that articulate how

experience is lived in relation to a specific institutional context; this highlights the socially situated understanding of subjectivity wherein the encounter with *other* (whether the social structure, language or an-other) could be what produces subjectivity. Having discussed subjectivity as a key concept of the sociopolitical approach, in what follows we discuss empirical and theoretical explorations of the turn in research on science education.

Empirical approaches to the turn towards an activist stance

There are not many examples of the empirical 'use' of the sociopolitical lens in science education. In what follows we describe two pieces of empirical research using the concept of subjectivity. The first is an analysis of biology textbooks in relation to neoliberal discourse and the second is an analysis of how a science teacher negotiates her practice under the discourses of standardised testing. We close the section with a discussion of an activist stance that resonates with the Latin American context.

Jesse Bazzul's critical discourse analysis of the Nelson Biology 12 textbook in Canada examines subjectivity within a neoliberal framework (Bazzul, 2012). Notably, a passage prioritising competition over collaboration without posing it as a question stifles balanced discussion among students. Bazzul links this to neoliberal discourse, where competition is emphasised as a mantra, reflected in the teacher manual's assertion that students are unaware of competition's role in science. While textbooks alone are not responsible for the neoliberal discourse, they play a significant role in shaping subjectivity within such contexts.

Maria M. F. Wallace (2019) examined the subjectivity of a novice science teacher navigating institutional pressures of standardised testing and teacher assessment. Through ethnographic study, Wallace observed classroom interactions and analysed conversations between the teacher and herself alongside evaluation rubric extracts. The teacher's subjectivity was shaped by institutional norms and the external gaze of evaluation, reinforcing the narrative of a 'highly effective teacher' (p. 974). Wallace utilised feminist poststructuralist perspectives and a humanist approach to science education theory, offering a reimagining of teacher subjectivity under the constraints of effectiveness, akin to Lather's (2012) concept of new scientific subjectivity.

In Bazzul's and Wallace's experiences of the sociopolitical turn, the mixture or varied use of different structural/poststructural, politicised approaches lead to a more critical and transformative science education which also engages with the activist orientation of the sociopolitical call. The sociopolitical call attempts to shift towards a more radical and activist approach to science and technology education (Alsop & Bencze, 2014; Rodriguez, 2019). This conceptualisation of the activist call resonates with the Latin American context because of both growing inequalities and the excluded and silenced knowledge production of those places that are non-dominant or have been colonised.

There are different approaches as to how to understand activism in science education; there are some authors who see the possibilities of activism in the school science curriculum and others in a broader sense who go beyond the school. Hodson (2003) stated that action in science education could be understood in two senses regarding the school science curriculum. The first relates to how the science curriculum incorporates the interests, needs, and aspirations of students at school;

the second to how it is oriented explicitly to a sociopolitical dimension. His proposal included the appreciation of the societal effect of technological and scientific changes, the recognition of how some decisions in science and technology respond to particular interests of certain groups, marginalising others, meaning that science education is linked with the distribution of wealth and power, to develop the possibility to take action, and to develop the students' own views and positions regarding these problematic issues.

A contested understanding is suggested by Alsop and Bencze (2014), who pointed out the sociopolitical call in a sense that is broader than what happens in school science and goes to the public arena. These two authors asked the dual question: 'What might activism offer to science, technology and education? What might science, technology and education offer to activism?' (p. 1). The book of which these two authors are the editors included the discourse developed over a five-year project, 'The Project for Activist Science and Technology Education', which was associated with the journal *Activist Science & Technology Education*. This aims to explore the theoretical and empirical possibilities, tensions, limitations, and experiences that the activist call is making to the science and technology praxis. It bears noting that this journal continues to contribute greatly to the role of activism in science education. Bazzul and Tolbert (2019) argued that the activist call in science education should move away from conservative forms of research in science. According to them, too much scientific knowledge comes from Western research that is unproblematically applied to other contexts. In that sense, science education should have space for larger social movements and 'non-dominant forms of knowledge' (Bazzul & Tolbert, 2019, p. 303), by adding diverse perspectives to the activist call coming from communities that have been marginalised.

Theoretical approach to the turn and theorising from Latin America

Science educators are grappling with the sociopolitical turn, primarily through theoretical discussions, occasionally supported by empirical examples. Roth and others explored this shift by integrating sociological and psychological perspectives in *Re/Structuring Science Education*, aiming to reconceptualise conceptual change (W. Roth, 2009). The authors in this edited volume utilised cultural studies, sociology, and discursive psychology to examine dialogue, discourse, culture, and history in science education practices. Bencze and Carter (2011) highlighted the impact of globalisation and neoliberalism on science education, suggesting that under neoliberalism, students are groomed either as knowledge producers or consumers, perpetuating existing economic disparities. Globalisation, termed a 'wicked' problem, is seen through the lens of the 'post-structural subject' by Bazzul and Siatras (2011), who advocate for critical pedagogy to counter neoliberal agendas. Carter (2014) suggests that the neoliberal discourse permeates society, urging educators to address its implications and consider avenues for activism and resistance within science education.

According to Carter (2014), this pervasive discourse of neoliberalism is so impregnated within society that it can be referred to as 'the elephant in the room' (p. 25), because it is the current common way that we unreflexively live, interpret, and understand the world. Carter (ibid.) pointed out that unpacking this discourse in science education could shift

the unpolitical stance of the field at the same time as exploring some implications for activism and resistance in science education.

Some science educators are concerned with issues of historically silenced groups or themes in science education. For example, Brandt and Carlone (2012) incorporated cultural studies of how the interaction between contexts and political issues influences the science classroom. These authors used ethnography to highlight ethnic and linguistic aspects of groups that have been excluded from participation in school science. Similarly, Fifield and Letts (2014), incorporating queer theories in science education, questioned how sexual education in science has been understood as a binary under a heteronormative regime to avoid talking about diversities or sexualities, unpacking, for example, the phrase 'science for all'. Kayumova (2015) posed the same call to explore the sociopolitical dimension by incorporating both feminist and postcolonial questions in science as a critical lens to read how knowledge production is undertaken in science education.

An example of a Latin American exploration of the sociopolitical in science education combines a Freirean pedagogy with a humanistic approach including dialogue in the classroom (Santos, 2009). Santos (2009) call is to understand, through critical reflection, the political role of science education by questioning the banking model of schools 'depositing' knowledge while students 'consume' it. Inside science education there are some critical voices raised against this Freirean approach because of its presumption of a 'unified, conscious, rational subject of humanism' (Lather, 2012, p. 1024). Still, some Freirean notions of emancipation or the banking model of education resonate strongly, especially in the Latin American context (Torres-Olave, 2021), owing in part to its process of (de)colonisation.

The term 'decolonial' emerged to protest against both colonisation and the idea of occidental modernisation in the Latin American context (Walsh, 2013). The decolonial question is posed as a way to trouble, for example, dominant discourses about science, attempting rather to break hermetic science education, and shift it towards transformation. According to Walsh (2013), decolonial pedagogies are in line with critical pedagogies in the sense that decolonial pedagogies are part of a bigger decolonial struggle that can induce theorisation and reflection as non-linear movements that are rooted in the idea of new ways of transitioning and new ways of being. The recent sociopolitical call in science education can be theorised and put into practice from current social struggles towards possibilities of resistance (Carter, 2014). In that sense, the Latin American experience could offer a rich context in which to develop this sociopolitical dimension of science education, which might add other perspectives of how knowledge is produced and understood, attempting to decolonise school science (Higgins et al., 2018).

In the context of science education, acknowledging that scientific discourse is not pure could open up the opportunity to ask who decides what knowledge is valid and why some categories of knowledge are universally accepted while others are not. In a recent example, Thomas and Vavrus (2019) pointed out their discomfort as facilitators in a CPD programme while explaining to the participating teachers why and who decided that Pluto is no longer a planet. From that discomfort they ask themselves 'how might global norms about "good" pedagogy reinscribe colonial hierarchies of knowledge and power?' (ibid., p. 2). These authors used the naturalistic approach based on the history of the people to problematise the statements of universality in relation to the colonial history of

specific knowledge. They aim to produce a decolonial praxis in a teacher training programme, using what they refer to as 'reflexivities of discomfort'.

Decolonial pedagogies are related to the understanding that teaching is not just instrumental (Walsh, 2013); in Freire's (1970) terms, pedagogy is a methodology inside and outside the school as a social fight for liberation. Connecting Pereira's (2019) 'boundary work' in STS with the reflexivities of discomfort ofThomas and Vavrus (2019) recognition of the institutional border of the school and the university as a limit allows one to reflect critically on the disconformity that those walls/boundaries could produce. This questioning may become decolonial by the Butlerian notion of 'asking after' the norms of knowledge production and its transmission, above all when the knowledge is understood as neutral and detached from its subjects with their different views of the world. As stated by Avraamidou (2020), positions that dispute those assumptions open spaces for 'multiplicity, diversity, subjectivity, and hybridity' (ibid., p. 4) to experience and acknowledge the many possibilities of being a science person, a process always already embedded sociopolitically.

Sociopolitical questioning associated with science education and the science curriculum

The relationship between science and science education has been widely explored, yet less attention has been given to how both are conceptualised, resulting in some paradoxes in the field. Science deals with themes of the material world such as life and living things, matter, the universe, amongst many others that are – or can be – compelling to many people (Millar & Osborne, 1998). Science has competed for a space in the school curriculum since the nineteenth century and most of the ideas that nowadays are part of science education came from that time (DeBoer, 1991; Sikorski & Hammer, 2017). Thus, science education has been concerned with ideas such as objectivity and 'the "truth value" of scientific knowledge' (Bazzul, 2016, p. 2), while trying to engage with more recent worldwide concerns such as the environmental crisis and social inequalities (Bazzul et al., 2019). During the twentieth century, the organisation of science education was dominated by psychological approaches to knowing and learning science, focused on the individual mind (W. Roth, 2009). In the late 1990s, it shifted to include a focus on social, cultural, and political aspects, and more recently an understanding that 'science education produces (and is produced by) particular material realities' (M. F. Wallace, 2018, p. 201), putting into question the 'taken-for-grantedness of a "good/true/right science education"' (ibid, p. 201). Science education with its paradoxical ideas and organisation is becoming – or must become – a site of struggle (Bazzul, 2016), where the people working on it might interrogate both themselves and the field to realise that 'becoming' (Carter, 2014).

Interrogating them(our)selves and the field is of value by, for example, addressing the question that Millar and Osborne (1998) raised, namely 'why does education in science matter?' (p. 7). To share with students the knowledge and products that science and technology have produced about the material world, to develop a sense of decision-making ability, or the empowerment and action about scientific issues are some of Millar and Osborne's sensible answers. Nevertheless, in trying to understand, for instance, why the interest of students in science decreases as students move through compulsory

education (e.g. Mujtaba & Reiss, 2014), or why science education is seen as irrelevant 'for and by the learners' (Stuckey et al., 2013, p. 1), some authors have shifted to asking how science and science education have been conceptualised (Carter, 2014). One illustrative area in which this question can be seen is the place of practical work, which is also contested. As a strategy, practical work in science education is widely considered to be essential to the point that it is identified as '*the* distinctive feature' in school science (Abrahams, 2011, p. 1). For some, practical work in laboratory lessons is associated with students following orders, becoming *less* able both to follow a procedure and to understand the complex relationship between science, society, environment, and technology (Bencze & Hodson, 1999), voicing doubts as to its value. However, others have pointed out that practical work can be effective if it is seen as 'minds on', by engaging mentally with scientific concepts and ideas, rather than just 'hands on', where the engagement is only through manipulating objects (Abrahams, 2011; Abrahams & Reiss, 2017).

Those kinds of contested understandings in science education move us to uncover how science education might be in dispute. One way to explore this is through the science curriculum. A curriculum is seen as being at the heart of education because it supposedly embraces the integrated, holistic, and narrative nature of education while being a bridge between teachers and the social context (Hökkä et al., 2010). What is that *heart* in science education? How is it developed and changed? How do teachers respond to those changes? And which is the subject produced in that context?

What is the science curriculum?

Many science educators working in different contexts have wondered what the aim of science education is or should be. For some, its aim, as with education's aim in general, is related to enabling learners to 'lead a life that is personally flourishing and to help others to do so too' (Reiss & White, 2014, p. 10). For others, there is significant consensus that 'the' aim is to achieve scientific literacy of the population, which means citizens who are informed and able to participate actively in a modern, democratic, and technological society (Holbrook & Rannikmae, 2009), engaging critically with science (Osborne & Dillon, 2008). In 1998, Millar and Osborne, with others, produced a report called *Beyond 2000: Science education for the future* which also asserted that scientific literacy is the primary goal. However, there is not a univocal voice as to what scientific literacy means (Vieira & Tenreiro, 2016), and, unfortunately, sometimes the term is seen only as the preparation of *future* scientists, irrespective of what students currently experience because they are considered as what they *can be* rather who they *are* (Aikenhead, 2005; Millar & Osborne, 1998). The *Beyond 2000* report 'had a major effect on curriculum development in England, Wales and Northern Ireland' (Reiss, 2018, p. 47) and was produced considering science education in that context; it is widely cited – 2308 citations on Google Scholar as of 24 May 2025 – and is also referenced in other geographical contexts. A recent example of its use can be found in Colombia, where the importance of including the Nature of Science in the curriculum was addressed (Ayala-Villamil, 2019), an emphasis which was not present before.

Even though scientific literacy is currently and worldwide singled out as the primary goal of science education (Vieira & Tenreiro, 2016), for some the main aim should be the integration of STEM (Science, Technology, Engineering and Mathematics) disciplines,

which, as a movement, appeared at the beginning of the 1990s (Martín-Páez et al., 2019). Freeman et al. (2015) stated that STEM is related to learning or working in the disciplines of the acronym from school level to, eventually, university level. Nevertheless, according to Carter (2016), STEM has neoliberal foundations that could be 'silencing other perspectives of science education' (p. 31), which is worrying, considering its wide acceptance in science curricula (Higgins et al., 2018). In South America, until recently, STEM education was not greatly in evidence (Tovar-Rodríguez, 2019). However, in Argentina, Chile, Ecuador, and Colombia there is increasing interest in integrating STEM disciplines as evidenced both by research within academia and in speeches from national educational institutions (ibid.). In Chile, STEM is part of the discourse of the national science curriculum which states: 'students should develop competencies to live and work in jobs that do not yet exist'. However, apart from just thinking about the *future* lives of students, there is no practical integration of the disciplines in the curriculum, nor are teachers trained to be STEM teachers. In a sense, STEM presents something of a blurred aim, and both it and the scientific literacy approach are informing Latin American science curricula from 'outside'. In Latin America during the 1960s and 1970s, the concept of 'Latin American Thought on Science, Technology and Society' (PLACTS in Spanish) emerged as a situated understanding of the STS (Science, Technology and Society) movement, aiming for endogenous technological development to overcome the social and economic inequalities of the region (Chacón, 2016; Jiménez, 2010). According to Chacón (2016), in the 1980s, PLACTS was seen negatively due to the neoliberal model which tried to stimulate a competitive technological market internationally where endogenous efforts were seen as inefficient and expensive. As Calsado (2020), p. 19) noted, 'the marginalized are prohibited from exercising their right to self-determination', citing, though, how an indigenous community in the Philippines disputed the 'dominant' curriculum by building a decolonised STEM curriculum. Similarly, McKinley and Stewart (2012) pointed out that there have been attempts to include indigenous knowledge in the science curriculum; however, this has too often resulted in a sort of 'caricature' (p. 542) of that knowledge. In this sense, 'one' curriculum defines what is taught and what is not in something called a 'selective tradition', which helps to maintain the privileged position, taking the knowledge of a particular group as the one that should be transmitted. From the silenced PLACTS or the decolonised STEM curriculum arise dilemmas, for example, issues of power and knowledge in science education, questioning if the aims should respond to multiplicities or universalities (M. F. Wallace, 2018). Another science education initiative that engages politically and socially with issues of power is STEPWISE (Science and Technology Education Promoting Wellbeing for Individuals, Societies, and Environments), aiming for students to discuss their current understanding of socio-scientific issues, considering social, political, economic, and ethical dimensions (Bencze, 2017). The sustainable socio-scientific (S^3R) model put forward by Morin et al. (2014) and the Sociocritical Problem-Oriented model described by Marks and Eilks (2009) are other science education initiatives that attempt to engage with local problems, towards a sense of ecojustice (Roth, 2010a) with a perspective which creates a confluence amongst 'science, environment and health' (Dillon & Avraamidou, 2020, p. 4).

Apart from the questions surrounding its aims or situatedness, the science curriculum presents challenges to the teachers who are called upon to implement it. Teachers typically find that this is a difficult task as they are expected to teach a huge amount of

knowledge. In general terms, when the science curriculum is rigidly developed, teachers lack a sense of ownership which makes it more difficult for them to teach it in the way it was intended (Ogborn, 2002). At this point it is worth problematising how the curriculum is developed.

How is the science curriculum developed?

In broad terms, changes in curricula are never-ending (Bantwini, 2010). Curriculum reforms aim to change educational systems which also affect the processes happening in classrooms (Couso, 2016), meaning that for schools and teachers 'curriculum change is currently the lived reality' (Jenkins, 2020, p. 179). The development of the curriculum is in line with a technical-rationalist approach managed by Ministry people, with power and influence, who review what is already in it, to generate alternatives and make recommendations for teachers to implement (Bencze & Hodson, 1999). Those changes are made by others, namely, curriculum developers, rather than determined by the actual practice of teachers (who are positioned as curriculum receivers) and students in classroom activities (Saracaloğlu et al., 2010). In Latin America, the process of curriculum development started under the European influence of Spain and France, drawing on how liberals or conservatives viewed the educational system, and is a process without teachers' significant participation, even if there is a collaborative design of curriculum materials (Couso, 2016). This results in a mismatch of what teachers and curriculum developers do.

Bencze and Hodson (1999) have pointed out the importance of 'changing practice by changing practice' as a way of conducting curriculum developments – involving action research processes – with teachers assuming multiple roles to fulfil the requirement to generate those changes. Teachers are called to 'reinterpret the fundamental concepts and methods of the respective disciplines in accessible, engaging, and powerful ways for students' (J. Smith & Girod, 2003, p. 295). Even though policy asks for those changes, it does not provide the opportunity for teachers to implement them, so how is this resolved? In that sense, curriculum innovation in science education is brought to schools in a top-down way, typically resulting in little change in classrooms (Couso, 2016). Bencze and Hodson (1999) advocated a participatory approach to curriculum development based on action research because the curriculum 'should be regarded as problematic and open to scrutiny, critical appraisal, and revision' (p. 525). Their approach attempted to create a *common curriculum* where teachers who know their students, school environment and conditions work collaboratively on issues related to the design and implementation of teaching and learning experiences. In this way, collaboration between teachers is seen as the best hope for school improvement (DuFour, 2007). Albashiry et al. (2015) explored experiences of collaborative curriculum development between students, teachers, and employers to develop a shared vision about the educational programme and how it should be developed and implemented, thus shifting the position of teachers from information providers or executors of others' ideas (Van Driel et al., 2012), challenging a current dilemma between '"knowledge production" and its implementation or "knowledge consumption"' (Couso, 2016, p. 55). So, we pose the question: how do teachers respond to curriculum changes?

How do teachers respond to curriculum changes?

In the realm of curriculum development, teachers often find themselves relegated to the roles of implementers, executors, and information providers rather than active curriculum developers. This profoundly impacts how teachers engage with and respond to curriculum changes. For instance, a study in South Africa highlighted how teachers viewed reforms as entailing increased workload, as time-consuming, and sometimes as inadequately supported, leading to dissatisfaction and challenges in adapting to them (Bantwini, 2010). Despite recommendations for teacher involvement in the developmental process, the onus often falls on teachers to navigate these changes without sufficient support. Similarly, in Turkey, teachers' insights in curriculum evaluation were disregarded, leading to feelings of dissatisfaction and disappointment (Saracaloğlu et al., 2010). Despite nominal participation in development committees, teachers perceived insincerity in Ministry efforts, undermining their role in the process. Conversely, in Australia, where teachers have more agency as curriculum developers, they exhibit greater enthusiasm and adaptability towards changes, citing administrative support, positive environments, and quality professional development as facilitating factors (Jenkins, 2020). This underscores the importance of empowering teachers in the curriculum development process. In England, the reception of curriculum reforms among science teachers varied, with contextual factors such as supportiveness influencing their attitudes towards implementation (Ryder & Banner, 2013). Recognising teachers' diverse identities and educational aims is crucial in facilitating effective curriculum changes.

In Chile, regarding curriculum changes, teachers are mostly considered curriculum implementers (González, 2015). However, the Chilean teacher workforce's response to the most recent curriculum change in the science curriculum was a national mobilisation in 2019 asking for that reform to be invalidated, amongst other demands to do with working conditions (F. Acuña, 2020). Even though the proposed changes were in line with the current focus of science education and many teachers agreed with them in principle, the 'usual' way to make curriculum reforms without teachers' participation resulted in a massive rejection of them (Torres et al., 2019). In Chile, the new curriculum and the new law that created the latest arrangements for teachers' professional development have a declared aim of boosting the autonomy of teachers. Potentially, such teacher autonomy could create the space for science teachers to engage in the reinterpretation and their own organisation of the curriculum. However, Chile's and other cases' experiences are similar in that teachers are presumed to be providers of information, or implementers of a curriculum designed by others; in this way, teachers become excluded from the curriculum developmental process.

Many of the authors reviewed here conclude their writing by wondering how the various frameworks imposed on teachers are meaningful for teachers who have the ultimate responsibility for using them in their classrooms (Bradley & Moodie, 2017; Bravo et al., 2019; I. Mitchell et al., 2017). We would add a further power-sensitive question related to the curriculum: How are the changes in the curriculum addressed by the schoolteachers in their classrooms? How do schoolteachers undertake these changes? The answer to these questions is usually sought in CPD programmes or other instances of work between teacher educators and teachers in service with the supposed aim of 'updating' the latter about current trends of

science education. Specifically, in relation to curriculum development and the role of CPD, the role of teacher educators is conceptualised as giving schoolteachers the necessary support to guarantee that the curriculum and its changes are 'implemented adequately' (Couso, 2016, p. 49). According to Ryder and Banner (2013), a very common policy concerning curriculum changes consists in using professional development to develop teachers' knowledge of the reform and how to implement it. In what follows, we develop a critical revision of CPD programmes in general and in science education in particular, reflecting on the roles of universities and teacher educators.

Challenges to CPD programmes under power-sensitive questions

In general terms, CPD is described as an education training that goes beyond the initial formation to be a teacher. CPD has sometimes seen a way to 'guarantee' that changes in the curriculum are implemented as designed by developing the knowledge of the teachers on curriculum reforms (Ryder & Banner, 2013); that is to say, curriculum reforms need CPD programmes (Uçan, 2016), yet it is also argued that for teachers, CPD programmes are needed when a new curriculum is introduced (Subitha, 2018).

CPD is singled out as essential in teachers' practice for maintaining or improving some standards in education and society, given factors such as increasing globalisation (R. Mitchell, 2013). In that vein, it is not surprising to see the OECD (Organisation for Economic Co-operation and Development) stating that '[e]ffective teaching is at the heart of a successful education system and there is a growing recognition that supporting teachers' professional learning from the beginning to the end of their career is critical to improve student outcomes' (OECD, 2016) in what they called a strand of 'continuing professional learning', followed by recognising that CPD has growing importance 'to respond to a fast-changing world and its challenges'. In the first quotation it is possible to read an aim oriented towards effectiveness – the words 'effective', 'successful', and 'improve' are used – which could be associated with the problematic 'best practice' mindset that closes down critical understanding of the complex and diverse task of teaching and learning (Lefstein & Snell, 2013). The second quotation sees the world as just one place, obliviating variability and asserting that it is rapidly changing, both features associated with the neoliberal agenda (R. Mitchell, 2013) which privileges economic growth and productivity, amongst other features.

Contested voices in regard to this understanding of CPD include what Clarke and Hollingsworth (2002) saw as the aim of professional development of teachers by recognising their unique and individual learning and their practice, not in a linear fashion but rather as a model of growth, anticipating its multiple and variable shapes. Similarly, R. Mitchell (2013) posed his definition of CPD, acknowledging the individuality of professional development as 'the process whereby an individual acquires or enhances the skills, knowledge and/or attitudes for improved practice' (p. 390). Mitchell's definition embeds the understanding of professionalism reflected in the word 'practice', which necessarily has to do with one's day-to-day work.

CPD is associated with professionalism in a contested way. When the CPD is not understood as continuous and the aim of the professionalism is misunderstood as being just training rather than being developmental (Núñez et al., 2012), the relationship

between CPD and professionalism is missed. Professional development could be a continuous lifelong learning process (Ávalos, 2002); however, initial and subsequent training are both tackled in very different ways in terms of laws, standards and aims (Day, 1999).

There is a close relationship between CPD and universities, as the latter are one of the most common institutions to conduct these programmes (Ryder & Banner, 2013). In so doing, there is also a closeness between universities and schools. However, neither schools' nor universities' organisational conditions are usually considered in the research pertaining to teachers' professional development, nor is the role of teacher educators within those spaces (Van Driel et al., 2012). Before delving into that relationship, in the following section we briefly examine features of CPD programmes, introduce a discussion on whether the process should be termed 'learning' or 'development', and review some experiences of CPD programmes in science education.

Professional development's features and aims: development or learning?

There are diverse approaches to understanding CPD programmes. For some, CPD is an essential process if teachers want to have their curriculum knowledge up to date, being 'wise' with respect to how they select and use what is written (Day, 1999, p. 221). In this understanding, the curriculum is central and if teachers *want* to pursue – or are asked to participate in – a CPD programme, it is assumed that this is just to be updated on what they do not know about the curriculum (Geldenhuys & Oosthuizen, 2015; Luneta, 2012), alongside aligning teachers' practices and policies and improving teachers' performance. In this sense, educational change can be seen as an imposition initiated by external factors rather than self-initiated due to teachers' recognition of a problem (Bell & Gilbert, 2005; Uçan, 2016). A different understanding – in line with the self-initiation of a CPD programme – argues that professional learning exists to improve teaching and learning of the teachers' own practice (Guskey, 2003), integrated at the level of personal practice (Vaillant & Cardozo, 2016) and taking into account schools' socio-cultural settings (Uçan, 2016) as well as understanding that CPD is 'a process rather than an event' (Subitha, 2018, p. 76).

A problem that Vaillant and Cardozo (2016) reported is that usually professional development is undertaken *on* teachers, so that they change their practices, and not *with* them. Additionally, Vaillant and Cardozo stated that CPD courses are brief and are not situated within the broader context of teachers' experience. Subitha (2018), writing about the situation in India regarding CPD, and the conclusions arguably apply worldwide, stated that the quality of CPD is 'far from satisfactory' (p. 77), where there is also a distance between the providers of CPD – usually centres of higher education and policymakers – and the daily practices and needs of schoolteachers in service or the needs of beginner teachers who receive little attention in teacher development. Here, schoolteachers are positioned, ultimately, as 'implementers of curricular and reform directives' (Subitha, 2018, p. 77), constituting a problematic position of simultaneously being 'the subject and the agent of change' (Uçan, 2016, p. 38).

Vaillant and Cardozo (2016) argued that while there is a large body of research on professional development, there is a gap between that research and the practice because professional development has neither 'satisfactory nor sustainable results' (p. 6). In this

vein, when thinking on how and under what conditions a teacher changes their practice, we can describe professional development as being conducted in a vertical way when there are policymakers who design the reform and a school which receives the reform without the teachers' active engagement, reflection or collaboration as professionals (González-Weil et al., 2014). That assumed teacher positionality resonates with both Giroux's duality of thinker/doer on curriculum development and also a positivist view of science where knowledge is accumulative, and new knowledge must be proven through empiricist scientific methods (González-Weil et al., 2014).

Lieberman (1996) identified three types of professional development: 'direct learning' which is short-term, delivered through conferences or workshops focused on resolving an issue (e.g. Lessing & De Witt, 2007); a second type that involves interventions inside the educational institution; and a third type undertaken outside the institution in collaboration with universities or other tertiary organisations. According to Freire (2002), short interventions undertaken outside the school are oblivious to the necessities of the local community; besides, they may not generate any knowledge or 'epistemological curiosity', as opposed to with what happens in purposeful praxis towards a process of 'conscientisation' (Freire, 1970). Other authors have also pointed out the fallacies of so-called 'one-shot' interventions (Clarke & Hollingsworth, 2002; Day, 1999) because of their emphasis on what schoolteachers are supposedly lacking. Related to the third type of intervention outside the school in collaboration with universities, the problem could be a lack of communication and an absence of expectations by those providing the CPD as to what teachers are capable of (Núñez et al., 2012). In that light, some have argued that professional development needs an intensive 'long-term collaboration between researchers and practitioners' (Couso, 2016, p. 56). Cavieres and Apple (2016) posed the question of how professional development occurs globally by disputing what the OECD understands as development when stating that professional development emphasises the autonomy and reflection of teachers (OECD, 2016).

A positive relationship between professional development and effectiveness is widely assumed in CPD programmes (e.g. Luneta, 2012), alongside the idea of effective/excellent teachers and effective schools, as in the above-mentioned OECD strand on continuing professional learning. The issue of effectiveness is associated with the question of how CPD should be evaluated. Amponsah et al. (2021) state that the aim of CPD is the 'successful implementation of effective classroom instruction' (p. 1). Similarly, Valdman, Holbrook and Rannikmae (2017), even though they declared that their intention is to conduct an 'authentic' CPD based on identifying teachers' needs by also developing a sense of self-efficacy, stated that CPD aims to develop 'a teacher to function effectively in the classroom' (p. 577). In 1996, Loucks-Horsley, Styles and Hewson stated some principles for effective professional development of science and mathematics teachers that are widely cited (Chval et al., 2008). One of these principles was that professional development must be guided by a 'clear, well-defined image of an effective classroom' (p. 3). The use of the notion of effectiveness in these examples is noteworthy because one could ask: Who is defining that image? This understanding of CPD as developing effective classroom instruction or functioning effectively under an idealisation of an effective image could be associated with the problematic notion of a single 'best practice' which dismisses the complexity and particularities of the teaching and learning in each experience (Lefstein & Snell, 2013).

Following this discussion of effectiveness, there is a discussion regarding how to name the teachers' process in CPD, namely, the question of calling it 'learning' or 'development'. Research has focused on how to develop some knowledge in relation to effectiveness, posing the issue on the other, as other people (Vaillant & Cardozo, 2016), rather than assuming a personal role in that process. Conversely, Hooks (1996) put the emphasis on 'how we learn', trying to add one's own responsibility to the process at the same time as positioning the actors. Clarke and Hollingsworth (2002) go further, talking about professional growth associated with a continuing process of learning, which is crucial for understanding teachers' change from a passive position to a complex process of learning (Subitha, 2018). Clarke and Hollingsworth developed the 'Interconnected Model of Professional Growth' (IMPTG), suggesting that the model could shift the perspective of change as done *to* teachers to 'a complex process that involves learning' when teachers are situated as learners in a process of professional learning (Clarke & Hollingsworth, 2002, p. 948). The model proposes a movement amongst different domains – personal, practice, consequence, and external – that are intertwined; change in one domain can have an effect on another by enaction and reflection. In that sense, the word 'development' is related to effectiveness in response to some standard/image defined by others, while 'learning' is related to one's own process, based on the position of teachers as learners from their own daily practices (Ávalos, 2002).

The positionality of teachers as learners has been explored in several studies (Wallace & Loughran, 2003; González-Weil et al., 2014; Shulman & Sherin, 2004) and in the case of science teachers, the concept of teacher as learner has also been used (e.g. Loughran, 2007; K. Smith & Loughran, 2017). In Loughran's understanding, the notion of teachers as learners is associated with an attitude of durable learning which involves collecting and analysing evidence about one's own practice and the response that this has on one's students. The position of teacher as a learner should be framed from the initial formation to be a teacher and the continuous process of training, and it could also be applicable to teacher educators in CPD programmes (Loughran & Menter, 2019). Learning in collaboration with others can shape what we do, how that is interpreted and who we are in that interaction (Lieberman, 2007), as opposed to the culture of individualism related to teachers working in isolation.

Learning communities – as social learning systems (Wenger, 2000) – are spaces of professional learning because they enable collaboration and shared meanings towards a sense of belonging, facilitating new ways of being (Lieberman, 2007). The conceptualisation of community has been widely explored in relation to teacher professional learning (Couso, 2016). When the practice of teachers engages with their community, they participate fully in working towards improved practice because of the skills, attitudes, and knowledge developed in that community (R. Mitchell, 2013), influencing classroom and school change. A community of teachers engaged in their professional learning can reflect on their own practice and share it with their colleagues. As per Kafyulilo (2013), teachers' collaboration is reported as influencing the students and the school.

There are different notions in the literature of how to understand and put into practice that sense of community. For example, Wenger (2000), following the idea that learning is a social process and should not be understood in isolation, proposed the concept of a community of practice, conceptualising learning as a 'lived experience of participating

in the world' (p. 3); another notion is professional learning communities (Hargreaves & O'Connor, 2018), which are understood as people sharing and reflecting critically on their practice as a collective aim (Stoll & Louis, 2007), in doing so, benefiting teachers due to being part of a professional learning community and improving students' learning. These kinds of communities are expected to be functioning inside every school (Stoll & Louis, 2007); however, as Stoll recognises, 'collaboration is sometimes mandated – or feels as if it is – making it repelling rather than compelling' (Stoll, 2020, p. 423), meaning that collaboration inside the school does not always work.

Even though the importance of communities of practice is widely recognised, there are few examples in the literature of long-term communities of science teachers where this kind of experience is reported. One example is the group named PEEL (Project for Enhancing Effective Learning) in Australia, which in 2008 reported 34 years of working together, sharing concerns about the prevalence of 'passive, unreflective, dependent student learning, even in apparently successful lessons' (I. Mitchell & Mitchell, 2008, p. 50). Another long-term community of science teachers is the group named PRETeC (Teachers Reflecting on a Transformative Education in Science) in Chile, which, as of 2025, has 15 years of sharing their practice in science education, discussing a range of aspects, such as the image of the science teacher and the importance of science in their own lives and the lives of their students (T. Acuña et al., 2016; PRETeC, 2024; Torres-Olave & Bravo, 2021). Tippins et al. (1993) pointed out the importance of communities of learners to reconstruct science teacher education. They stated that these communities not only aim to (re)signify the importance of collaboration and collegiality but also highlight learning as a 'life-long endeavour' (ibid., p. 69) which affects all participants of the community. In what follows, we examine other experiences of professional development in science education.

Proposals and experiences of CPD programmes in science education

There are three strands of professional development that are notably related to this exploration. The first brings attention to a type of professional development based on personal, professional, and social domains to review teachers' own practice (e.g. Bell & Gilbert, 2005), which is closer to our own experience of providing CPD programmes. A second strand critically analyses the way CPD programmes are usually evaluated and describes this as typically bypassing what is really happening with respect to teachers' learning (e.g. Aldahmash et al., 2019). A final strand elaborates topics addressed in professional development in science education and proposes strategies for richer CPD, mostly based on a sense of community and collaboration between participants.

In 1996, Bell and Gilbert proposed a model of professional development based on a three-year study conducted in New Zealand. According to them, a group of science teachers changed their classroom teaching from a transmissive approach to an approach that helped students build their own knowledge, by questioning their (the teachers') previous ideas, based on reflection on their learning (Simon & Campbell, 2012). Bell and Gilbert's model proposes three intertwined domains: the *personal* (involving feelings, motivation, availability, and commitment); the *professional* (referring to knowledge, conceptions, and visualisation of the response of the practice in students); and the *social* (related to the value of the collaborative

work and the context). According to Bell (1998), this reconstruction occurs in interaction with others, where reconceptualisation of the meaning of teaching science becomes the first step to changing one's practice.

Studies on CPD programmes in science education have addressed specific themes within science education (Aldahmash et al., 2019), such as scientific inquiry, inquiry-based science education (IBSE) and learning outside the classroom (Martins-Loução et al., 2020). Other examples include a CPD model focused on inquiry-based learning (IBL) in science education which contemplated teachers conducting lessons based on the students' own questions while analysing them as part of a CPD course (Kurtén & Henriksson, 2021), and an inquiry approach in a chemistry laboratory which also incorporated teachers delivering a lesson with inquiry-type experiments to be analysed across the whole group who participated in the course, contributing to their professional development. These kinds of CPD programmes based on inquiry are related to the first author's own experience of conducting a CPD programme, where the programme had as one of its main foci scientific inquiry, an aim of the current Chilean science curriculum. Aldahmash et al. (2019) also pointed out that CPD programmes based on communities of practice, action research and teachers' research have received the most attention from researchers as types of professional development. For instance, action research is quite often employed in science education research on CPD (Eilks & Markic, 2011; González-Weil et al., 2014; Mena et al., 2017) and curriculum change (e.g. Bencze & Hodson, 1999) in the format of Participatory Action Research (e.g. Eilks & Markic, 2011) or action research that is collaborative (e.g. Chou, 2011; Herbert & Rainford, 2014). Eilks and Markic (2011) proposed a long-term (six-year) cooperation between science educators and science teachers, connecting their results with the IMPTG model of Clarke and Hollingsworth (2002). In their conclusions, Eilks and Markic pointed out that the participation of both science educators and science teachers has an important impact on the relationship between schools and universities. Similarly, Herbert and Rainford (2014), in an action research project on the experiences of two teacher educators and an in-service science teacher, pointed out the importance of the generated 'third space', to reconceptualise teacher education mediated by action research and the school-based collaboration which also allowed collaboration in multiple settings (combining university and school). What seems to be a relevant aspect of the way that CPD is conducted is the need for the involvement of all who are participating in the programme, namely, teacher educators and schoolteachers. Van Driel et al. (2012) conducted a review regarding the professional development of science teachers and concluded that something is missing in the relationship between the role of the teacher educators/facilitators and the outcomes of professional development. In the same vein, Lumpe (2007) made an explicit call to science educators to '[s]top facilitating one-shot workshops. Work closely with schools to foster professional learning communities. Get to know school systems and staff members. Become part of a learning community yourself' (p. 127). Here, it is worth asking who are the teacher educators in the professional development programmes? Whose professional practice is developed? And in what institutional conditions does professional development occur? These questions are addressed in the following section.

Professional development and university–school relationships

The dynamics of the university-school relationship are complex and often characterised by power imbalances, particularly evident in CPD programmes. Despite recognising the potential for mutual learning, these programmes frequently reinforce traditional roles of teachers as facilitators and learners, neglecting genuine collaboration (Day, 1999; Lumpe, 2007; Tippins et al., 1993). For instance, Thody (2008) exemplifies this imbalance by suggesting how academia can 'persuade' teachers to adopt theoretical frameworks without critically examining the applicability of research to classroom practice. This one-sided approach underscores the need for a more equitable research–practice partnership, where teachers are positioned as researchers, shaping their own professional development (Guerrero & Reiss, 2020).

The relationship between universities and schools is further complicated by social factors such as cultural discourses and economic disparities, often resulting in asymmetry (Lumpe, 2007). While CPD aims to bridge the gap between academia and practice, entrenched boundaries persist, hindering genuine collaboration (Bakx et al., 2016; Tsui & Law, 2007). In Latin America, concerns about this relationship are growing, with limited interaction between universities and schools impeding the translation of theory into practice (Vaillant, 2019). This disconnect raises questions about the role of teacher educators in CPD programmes, a subject that remains underexplored in the literature (da Silva & Neto, 2016). As a result, research on teacher educators has mostly been undertaken through self-study (Cochran-Smith et al., 2019).

Acknowledging the importance of teacher educators' learning is crucial, yet often overlooked (Van der Klink et al., 2017). In Latin America, there has been a call for teacher educators to reflect on their theoretical frameworks and practices, emphasising their role in professional development (Vaillant, 2019). However, institutional constraints such as time, workload, and lack of support impede teachers' professional growth (Van der Klink et al., 2017). Parejas and Margalef (2013) pointed out some other dilemmas while exploring the possibilities of reflection by teacher educators. While engaging in collaboration, teacher educators presented intra- and interpersonal, as well as external, dilemmas such as the time needed for reflection. Personal beliefs concerning teaching and learning, as well as the beliefs of others and intrapersonal dilemmas such as frustration about incorporating new strategies of teaching, are among the matters requiring adequate time for reflection. Educational institutions bear responsibility for fostering an environment conducive to teacher educators' development (K. Smith, 2003).

Moreover, the increasing demands placed on teacher educators, particularly regarding research and publication, raise questions about institutional priorities and their impact on professional development (Van der Klink et al., 2017). A recent exploration on teacher educators' learning, not specifically in science, can be found in Vanderlinde et al. (2021), who stated that since 2013 there has been increasing interest across Europe in the professional development of teacher educators. Even though the teacher educator that is the focus of their research is a teacher who teaches mostly pre-service teachers, the missing support for education and professional development can be applied to teacher educators in CPD

programmes for in-service teachers as well. This highlights the need to re-evaluate the functioning of educational institutions and their commitment to supporting teacher educators.

In summary, the university–school relationship in CPD programmes is fraught with challenges stemming from power imbalances, social factors, and institutional constraints. Addressing these issues requires a concerted effort to promote genuine collaboration, recognise the role of teacher educators, and prioritise professional development within educational institutions. Then it bears asking, how does that educational institution function?

Professional development and the neoliberal university

In many parts of the world, as we have argued, universities, as well as other institutions, have been permeated by a neoliberal, business-like logic (Amigot & Martínez, 2013), with managerial understandings related to the production and dissemination of knowledge. Cannizzo (2018), quoting Stephen Ball, pointed out that the transformation of public education to a market-oriented mindset has three main policy technologies: 'the market, managerialism and performativity' (p. 215). Privatisation of the university is positioning students as consumers while academic staff have seen deteriorations in their working conditions. Besides, increasing casualisation in academic employment is transforming the university to a 'fast' academia (Gill, 2009). All the above-mentioned could mean negative reverberations in activities where the university is involved, such as CPD programmes.

Blackmore and Kandiko (2011) pointed out that as a result of privatisation, many academic activities are not paid at all or poorly paid; this also has to do with fast academia because there is a sense of 'always on' availability to respond to increasing requirements (Gill, 2009, p. 9). In that sense, university workers feel more pressure, to the point of feeling that their working environment is toxic (Cannizzo, 2018). As developed in the section on subjectivity, this marketisation of the universities is producing a subject who is hyper-productive – a hyper-agentic academic who minimises their institutional context while maximising their agency (Fardella, 2020).

In Chile, since the time of the dictatorship (1973–1990), universities, as well as other institutions and settings, have experienced progressive neoliberalisation (Fardella, 2020), which has imposed a sense of competition and individualism on how to conduct academic work. Besides, a high percentage of academic staff in Chilean higher education, nearly 60%, suffer casualisation of their employment with 'unstable part-time contracts with little institutional support' (Montenegro, 2016, p. 528), mostly in private institutions. In this scenario, the role of teacher educators regarding their own professional development is silenced by the conditions in the university (cf. Bazzul, 2016). Carter (2014), quoting Picower, stated that under the regime of neoliberalism the role of the teacher educator should not be less than activism, otherwise there would be little chance of changing the conditions.

Discussion and conclusion

Curriculum design – sociopolitical questioning

There are two key strands in research on the subject formation in curriculum design that are particularly relevant to this exploration. The first of these foregrounds the way that subjects/teachers have been excluded from processes of curriculum development (e.g. Bencze & Hodson, 1999), related to a sense of ownership of the curriculum (Ogborn, 2002). The second key strand goes further; rather than just noting this exclusion, it attempts to explain it using the concepts of 'cultural myths' (Tobin & McRobbie, 1996) and decolonisation (Gandolfi, 2021).

In Pietrocola's (2017) understanding of the curriculum, the exclusion of teachers from the changes should no longer exist because 'the science curriculum, more than any other field of knowledge, was burdened by social and political pressure to change in order to adapt to modern challenges and needs' (p. 2). We would argue, however, that rather than considering that pressure as just a burden to change, the sociopolitical influence needs to be examined so as to understand the origin/context in which the curriculum is changed. As we have argued, schoolteachers are typically positioned as implementers, information providers or executors and less as curriculum developers themselves. Related to this and drawing on the sociopolitical approach, there are some power-sensitive questions that can be posed in relation to curriculum development, such as: Who made the changes to the curriculum? Whose practice and knowledge is legitimised in that development? And, in turn, whose knowledge is not legitimised?

According to Bencze and Hodson (1999), the development of a curriculum is managed by Ministry people/policymakers who review what will be included to make recommendations for teachers to implement. In that sense, the changes are made by others instead of being informed by the practice of the teachers (Saracaloğlu et al., 2010). Sokolowska et al. (2013) undertook an analysis of science curricula in ten EU member states, acknowledging the affective component in the intended, implemented, and attained curriculum, and concluded that what is happening in classrooms is rarely 'detected in legal documents' (p. 10). Ogborn (2002, 146) argued that 'teachers are the true owners of a curriculum' and, in that sense, curriculum implementation could be successful when teachers become curriculum-makers and not just implementers (cf. Bencze & Hodson, 1999). Ogborn (2010) underlines how academic researchers need to have a sense of modesty in regard to the extent to which research informs curriculum development, as do curriculum developers in terms of what their contribution could be, while also respecting the experience of teachers' practice as equally valuable. On the same lines, Giroux (1990) pointed out the typically reduced role of schoolteachers when thinking on curriculum development and other changes:

> What is evident in this traditional approach [of curriculum development] is that it organises school life around experts in curriculum, instruction and assessment, who are in fact assigned the task of thinking, while teachers are reduced to the category of *simple* executors of those thoughts. (p. 175)

Within this perspective, curriculum developers are positioned as the thinkers – mostly outside the school – who 'wish' to improve the quality of science learning in schools with

their ideas, while schoolteachers are simple implementers of those thoughts, in a very traditional understanding of teachers' practices. This understanding ignores, on the one hand, teachers' ownership of the curriculum and their agency as reflexive intellectuals (Giroux, 1990) and, on the other hand, the sociocultural and political setting where teachers enact their professional lives (Tobin & McRobbie, 1996), in doing so negating the institutional factors that surround their practice.

In their exploration of the perceptions of teachers regarding the incorporation of socio-scientific issues (SSI) in the Korean science curriculum, Lee et al. (2006) concluded that even though the teachers gave value to the incorporation of the SSI aspects within their secondary lessons, the lack of time available and the cultural pressure to prepare their students' entry to higher education institutions constrained the possibility of developing the SSI curriculum requirements. Thus, there was a clash between the policy requirement and the institutional culture, making it impossible for teachers to implement or for students to make sense of what was asked in the curriculum.

Influenced by Tobin and McRobbie (1996), who posed the idea of cultural myths in the chemistry classroom, a question worth asking under the sociopolitical approach is: What are the cultural assumptions – e.g. assumed asymmetrical relations – between policy-makers and schoolteachers regarding the curriculum's plan and enactment? Notably, it would be productive to explore how potential cultural myths could be constraining the science classroom with assumed power distribution rendering teachers and students powerless. Tobin and McRobbie finished their study by stating that '[t]he science curriculum is embedded in a sociocultural matrix and it is likely that reform can only be initiated and sustained if the shared beliefs throughout a community support recommended changes' (p. 239), that is, if the changes make sense to the ones who live in that context, namely, teachers and students. Such claims open the space to collaborative curriculum development, towards embracing an effort of decolonising the curriculum. This would allow a rethinking of how a curriculum engages with its context and diversity, disrupting colonial and universalised assumptions of what needs to be taught (Gandolfi, 2021). Decolonising curriculum and pedagogy is a movement that to date is more closely related to higher education (Shahjahan et al., 2021). However, it can be applied to secondary education and specifically to the secondary science curriculum (Gandolfi, 2021). Decolonising the curriculum emerges from the recognition that the curriculum is legitimising, validating or settling particular systems of knowledge production, e.g. western science (Gandolfi, 2021), while others become marginalised, e.g. indigenous knowledge in the science curriculum (Calsado, 2020; McKinley & Stewart, 2012). The meaning of decolonisation cannot be related to abstract and universal efforts; according to Mignolo and Walsh (2018), it should gaze back at 'who is doing it, where, why and how' (p. 108), as power-sensitive *'W'* questions that are important to ask of curriculum development. In this sense, decolonising is contextual, with political and epistemological consequences in terms of geographical, disciplinary, institutional, and stakeholder settings (Shahjahan et al., 2021).

CPD programmes – sociopolitical questioning

In the literature, there is an oft repeated call for a reconceptualisation of professional development which means, from the perspective of subjects/schoolteachers: connecting

the learning to the experience (Wallace & Loughran, 2003); involvement of schoolteachers in the design of their own professional development (Geldenhuys & Oosthuizen, 2015; Luneta, 2012); adaptation of any CPD material to local areas; consideration of social and cultural institutional settings of the particular schoolteachers' context (Aldahmash et al., 2019; Subitha, 2018) that also reconceptualises teachers' reflections incorporating social and critical dimensions (McArfdle & Coutts, 2010); and promotion of a culture of collaboration amongst teachers (Bantwini, 2019), amongst others. From the perspective of teacher educators, this reconceptualisation means the consideration of their own professional development (Cochran-Smith et al., 2019; Montenegro, 2016; Vanderlinde et al., 2021), the promotion of reflection on their practices with the support of their institutions (da Silva & Neto, 2016), and their involvement in collaborative and participatory action research projects (Eilks & Markic, 2011; Herbert & Rainford, 2014) or in CPD in general, amongst others. In this context, the two of us feel called to reconceptualise our own roles in CPD courses as teacher educators. In the case of the first author, what does it mean to run a CPD programme funded by the Ministry of Education in Chile since 2015 and with a special focus since 2016 on the subject matter of her own PhD? What does it mean to her colleagues, facilitators/teachers or schoolteachers, who occupy the role of participants/students in the context of the CPD? In doing so, in her case, this reconceptualisation of the CPD programme means also to make explicit her positionality regarding professional development of schoolteachers and her own.

For any teacher educator conducting CPD programmes, the sociopolitical approach could help shape the reconceptualisation of CPD programmes by incorporating power-sensitive questioning about: the way that the CPD is designed and conducted; the professional development of teacher educators; the critical lens on recent incorporations within the science curriculum; and a broader discussion on whether the process should be called 'learning' or 'development'. One can also ask: What does it mean to consider the power asymmetries between universities and schools or the position of teacher educators as learners in a neoliberal context? In that process, where both learn, who decides what is learnt? Who decides what is *effective* CPD? Why is CPD usually conducted outside the school? Why is the path to becoming a teacher educator less explored? What is the context in which teacher educators develop their practice? With these questions, the two of us feel called to attempt to undertake what Simon and Campbell (2012) identified as the deep reconstruction of what it means to be, in our case, teacher educators.

In this review, we have mapped some key approaches and debates in the literature on the sociopolitical turn as a way in which this critical lens might problematise school science curriculum development and professional development programmes. Specifically, we have traced: key notions of the turn, such as subjectivity and how it has been addressed; curriculum development and schoolteachers' participation in it; and the role of teacher educators and CPD programmes in science education. The three main arguments related to the production of subjectivity are as follows. 1) The sociopolitical turn is a call to break the impenetrability of science education by drawing on notions/questions/methods from other fields to question the science education field, thus transgressing its boundaries where a conceptualisation of subjectivity is useful to highlight the socially situated understanding of the term. 2) The science curriculum has many aims that are often presumed to hold globally (scientific literacy is currently an aim in countries of Europe and Latin America), which raises the

question of its situatedness and how, for example, it deals with issues of power and knowledge in different societies. In terms of curriculum development, schoolteachers are usually treated as implementers, executors, or information providers, and only rarely as developers. 3) A common policy concerning curriculum changes consists of using professional development programmes delivered by universities, creating a distinctive university–school relationship. Often, the role of the teacher educator is conceptualised as giving schoolteachers the necessary support to help ensure that the curriculum and its changes are 'implemented appropriately'. Under this conceptualisation, the professional development of teacher educators is omitted because the focus is on developing the schoolteachers' knowledge; the university and the school as institutions are unquestioned in the CPD space.

Alongside this argument, we have provided traces of the potential contribution of this work which is not by proposing cut-and-dried solutions but rather generating a struggle (in curriculum development and teachers' professional development under a sociopolitical questioning). The exercise to imagine what is and is not there (the relentlessly rejected in Derridian terms) allows us to think about how the mindset of presence – a dominant understanding of things like the neoliberal agenda or the idea of 'best practice' in education – closes down the possibilities of differed meanings. A trace 'is not at the start of things, it is not the origin, because the idea of origins is complicit in the logic of presence' (Henderson, 2015, p. 45). That logic of presence makes a defensive barrier, defending it in a way that is totalising (ibid.). If the way that the curriculum, professional development, and the practices of teachers are understood in the logic of presence – hegemonic understandings of certainty – what/who is not present is positioned outside that defensive barrier; therefore, it is/they are relentlessly rejected. Following Haraway (2016), one needs to stay with the trouble, imagining, in a provocative way, what *is and is not there* in a particular experience concerning the science education field.

In concrete terms, we found some horizons in terms of contributing methodologically and theoretically to the science education field, for example, exploring the notion of subjectivity related to the sociopolitical call, which can contribute to exploring the very subject production as researchers in the field and to an initial conceptualisation of shifting subjectivities as people who work in science education looking to other fields. Now, as further exploration, the arguments developed here might lead us to explore more in other areas with other authors (e.g. Michel Foucault, Bruno Latour, those who work in semiotics) to keep theorising, using other tools from cultural studies, sociology of education or philosophy to add to theories of subjectivity. Thus, we have drawn on research in science education that already draws on theorists from sociology and philosophy, and there is further work to be done, playing with different ways these ideas can contribute to the field and to the sociopolitical turn.

Our final reflection, which is at the same time an invitation to us and to others, is to continue exploring through the use of various notions (such as subjectivity), borrowed (or purloined) from different fields, as well as remembering the often dismissed fact that science educators (schoolteachers and teacher educators) are political subjects whose subjectivity should inform the science education field (in this case science curriculum and professional development) as recursive attempts to reimagine absent

possibilities of what it means to be a science person and what science education is and can be.

Note

1. On a personal note, we bring Mario Bunge (1919–2020) into this discussion because he is a Latin American (Argentinian) philosopher and physicist whom the first author read during both her biology and master's degree. At that time, what struck her about Bunge was his effort to make a distinction between what he called formal, factual science, and non-science, while putting factual science above all. Now she *re*reads his effort as going in the opposite direction to what the sociopolitical call is trying to do.

Disclosure statement

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