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Towards a socio-ecological practice of mathematics teacher education

Hacia una práctica socioecológica de la formación del profesorado de matemáticas

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Abstract ∞ This theoretical article is a response to UNESCO's call for a new social contract for education, in the context of mathematics teacher education. The article sets out four principles behind "socio-ecological" practices in mathematics education: not taking nature as a fixed background for concerns; avoiding the epistemological error of taking the individual as the unit of learning; questioning what is centred in our work; moving towards a dialogic ethics. The article considers the "what" and the "how" of mathematics teacher education, from this socio-ecological perspective. In terms of the "how", it is argued a dialogic ethics prompts attention to the potential for a mathematics teacher educator taking a "meta-perspective" in relationships with prospective teachers, recognising those prospective teachers as "teachers", from the start of a teacher education course. In contexts where the "what" of mathematics teacher education is highly constrained, the "how" of socio-ecological practices may still be possible to enact.

Keywords ∞ Socio-ecological; Mathematics teacher education; Teacher education; Futures (of society); Ethics

Resumen ∞ Este artículo teórico es una respuesta al llamamiento de la UNESCO en favor de un nuevo contrato social para la educación en el contexto de la formación de profesores de matemáticas. En el artículo se exponen cuatro principios en los que se basan las prácticas "socioecológicas" en la educación matemática: no tomar la naturaleza como un trasfondo fijo de preocupaciones; evitar el error epistemológico de tomar al individuo como unidad de aprendizaje; cuestionar lo que está centrado en nuestro trabajo; avanzar hacia una ética dialógica. El artículo considera el "qué" y el "cómo" de la formación del profesorado de matemáticas desde esta perspectiva socioecológica. En términos del "cómo" se argumenta que una ética dialógica presta atención al potencial de que un formador de profesores de matemáticas adopte una "metaperspectiva" en las relaciones con los futuros profesores, reconociendo a estos futuros profesores como "profesores" desde el comienzo de un curso de formación. En contextos en los que el "qué" de la formación del profesorado de matemáticas está muy limitado, el "cómo" de las prácticas socioecológicas aún puede ser posible de promulgar.

Palabras clave ∞ Socioecología; Formación del profesorado de matemáticas; Formación del profesorado; Futuro (de la sociedad); Ética

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1. Introduction

This theoretical article sets out some practices consistent with a "socio-ecological" approach to mathematics education and argues for how these practices can be applied to the context of mathematics teacher education. The need to consider change is pressing, as a result of at least two major forces, the first being the ineluctable deterioration of earth systems (with all the social and political upheaval and injustices this is provoking and exposing), and the second, being the strange inaction of the global community in the face of existential threat. Latour (2008) suggests we both know and do not know the perilous state of the planet. And, indeed, in relation to mathematics education research, there is a strange sense of "business as usual" in relation to the focus of journal articles and conference proceedings (Boylan & Coles, 2017).

There are, of course, also many groups pushing for change. The Organisation for Economic Cooperation and Development (OECD, 2019), in developing their "Learning Compass 2030" have called for a transformation of education, to meet the challenges of the future. The United Nations Educational, Scientific and Cultural Organisation (UNESCO) has called for a new social contract for education. By social contact, UNESCO mean "norms, commitments and principles that are formally legislated as well as culturally embedded" and they call for "a shared vision of the public purposes of education" (UNESCO, 2021, p. 2). UNESCO propose three foundational questions: "What should we continue doing? What should we abandon? What needs to be creatively invented afresh?". And they offer the following foundational principles: "assuring the right to quality education throughout life", and "strengthening education as a public endeavour and a common good" (2021, p. 2). Teacher education and (my focus in this article), mathematics teacher education, clearly has a role to play in any change that might result from engaging with the foundational questions and principles.

This article thinks through what a new social contract might mean for mathematics teacher educators, focusing largely on ethics. The next section sets out the broad ideas behind a socio-ecological perspective, and then applies those ideas to the context of mathematics teacher education. A distinction is drawn between the "what" and the "how" of teacher education and the focus is primarily on the how, since this is an aspect of practice that can potentially be changed within institutional constraints. One overall argument will be the significance of meta-communication to the ethics of a socio-ecological practice.

2. A socio-ecological perspective

The term socio-ecology has been used in many contexts. Bronfenbrenner (1979) proposed the idea of a socioecological psychology and urged psychologists to consider the wider contexts driving individual behaviour, which cannot be replicated in laboratory experiments (i.e., pointing to the limitations of laboratory-based research). Some thirty years later, the idea of a socioecological psychology experienced something of a revival (Oishi & Graham, 2010), again with an explicit focus on understanding and explaining individual behaviour through consideration of

wider, ecological, factors. Bronfenbrenner's work led to the development of "ecological systems theory" and is used in a range of fields (e.g., Boons, 2013); within mathematics education research, his term socio-ecological has been used (Louie & Zhan, 2022), in a commentary article on a special issue about equity. Bronfenbrenner conceptualised five layers of social activity, showing how local settings and interactions effect individual behaviour and development. Louie and Zhan (2022) use the framework to focus on power, and the ways that institutional structures and ideologies interact with individual thoughts and feeling "to organize (in)equity" (p. 355). They use the framework to illuminate, powerfully, the mutual dependencies and influences across layers.

Work within a socio-ecological psychology, as distilled above, has a focus on the individual and explaining individual actions and developments, through recourse to the wider systems in which individuals are embedded. Such a focus is made clear in depictions of Bronfenbrenner's diagram of interacting layers, where the individual is at the centre of the image, which the outer layers (microsystem, mesosystem, exosystem and macrosystem) help to explain. With a group of scholars, I have been using the phrase "socio-ecological" (Coles, le Roux, Solares-Rojas, 2022) to point to something slightly different, where the intention is precisely to move away from a focus on the individual. We take inspiration from work that has considered the socio-political dimensions of mathematics education (Valero, 2004) and seek to extend this into the ecological. In Coles (2022), I proposed four key ideas within a socio-ecological perspective, drawn from related strands of work (e.g., within cybernetics and post-humanism): (1) not taking the ecological (or "nature") as fixed background for other concerns; (2) working against the "epistemological error" of taking the individual as the unit of survival, evolution and learning; (3) questioning what gets centred in our research; (4) a dialogic ethics. I will elaborate on each one of these in turn, before moving on to how they might be applied to mathematics teacher education and, in the process, helping think about: "What should we continue doing? What should we abandon? What needs to be creatively invented afresh?".

2.1. Nature is not a fixed background

In researching, for example, classroom dialogue, mathematics educators have generally not paused to consider the quality of air teachers and students are breathing, in order to speak. In focusing on the dialogue in classrooms, we have generally taken nature as a constant background that does not need to be given attention. We have assumed that things like air quality are stable and therefore can be ignored in our analysis. And, for many years, this has surely been an appropriate assumption. And yet, in a global context in which it is estimated by the World Health Organisation that 90% of humans live in areas where air quality is below safe standards, the assumption of a fixed (and therefore benign) ecological background to the concerns of mathematics education seems increasingly hard to hold.

A socio-ecological perspective prompts a consideration of the ecological systems which support social interaction (and how socio-political systems interact with ecological systems). How might our research concerns alter, if we

acknowledge (for example) that a majority of children in the world are learning mathematics in classrooms where the air quality is bad for their health? At the least, perhaps, we might draw attention and point out when we are taking nature (or our ecology) as a fixed background to our concerns.

It is not an easy task to say what "nature", or "ecology" mean (I take the words as synonymous), in the way used in this article. The idea of nature, as a fixed background for our concerns, seems to imply that our concerns are not a part of nature. And yet, from a socio-ecological perspective, that cannot be the case. So, nature and ecology gain an odd topology, of encompassing all living processes in the world, of which we are therefore a part and yet, sometimes being taken to be separate. The dash within socio-ecological, is perhaps similar to the dash in the concept "space-time"; we know (if we believe the theory of relativity) that space and time are not separate, and yet common discourse continues to take them as such. Similarly, we frequently take the social as separate from nature/ecology (assuming one as fixed background for the other) when they are inseparable.

2.2. Epistemological error

A key starting point for my own thinking about socio-ecological ideas is the seminal text "Steps to an Ecology of Mind" (Bateson, 1972). Bateson proposes that Western society is gripped by an epistemological error and this recognition, for me, is at the heart of what I mean by a socio-ecological perspective. And, the fundamental epistemological error Bateson analyses, in contemporary life, is the focus on individuals as the unit of survival, evolution and learning. This error leads to a disposal society and ignores the inevitability that a system which disposes of its environment, disposes of itself (Wilden, 2001). Focusing on the survival of individuals blinds us to how individual existence is dependent on eco-systems.

An alternative epistemology starts from a recognition of the symbiosis of living systems. Rather than individuals, a socio-ecological perspective proposes that *relationships* are the units which survive, evolve and learn. It is perhaps easiest to approach this idea in the context of evolution. The incredible co-ordination and mimicry of species, such as orchids and wasps, is hard to fathom from a perspective that imagines each individual species evolving as a unit. However, a simple translation of thought, to imagine ancient orchids and wasps coming into a relationship and co-evolving (Maturana & Varela, 1987) over millenia, perhaps makes the extraordinary co-ordination of colours, shapes and behaviour more explicable. It is the relationship between orchid and wasp which has evolved.

Harder, perhaps, is to shift away from viewing the individual as the unit of learning. Epistemology seems geared towards a focus on the individual as the seat of knowing. Constructivist learning theories aim to explain the development and change of individuals. It seems almost heretical to consider that the individual may not be the unit of learning. And yet, for example, socio-cultural theories (Radford, 2021) point us to the manner in which individual actions are embedded in complex webs of interaction. Bakhtin (1993) alerts us to the way in which the words we use have a history and carry the intentions of others, even as they come from our

mouths. The neuroscientist Varela (1999) suggested the mind is not in the head, but is extended to the body and tools, and that minds are deeply and intimately connected, in the sense that consciousness is public and reciprocal. From these relational or process perspectives, learning is not the property of an individual, but of a relationship.

Such relational perspectives on learning, offer one way to embody the OECD's (2019) "transformative competencies" of "creating new value; reconciling tensions and dilemmas; taking responsibility". Recognising my own embeddedness in a socio-political ecology is part of a recognition of responsibility. Not identifying with "myself" as a sole source of beliefs is something I may need to work on, something I may need to do differently. Recognising my own interdependencies, and those of others, can be a factor in reconciling tensions. As a mathematics teacher or teacher educator, shifting away from a focus on the individual as the unit of learning implies not viewing individuals as the sole cause of their actions. Working with a student struggling with a mathematical concept, or a teacher struggling in a school, an educator needs to stay attuned to the contingent and changeable nature of performance and avoid the all-too-easy slippage into accounting for observations through taking individuals as the source of actions.

2.3. What gets centred in our research?

Mathematics teacher educators (MTEs) have only recently come into focus as a research topic and yet the focus on MTEs follows a line of, quite proper, human concerns within mathematics education (i.e., a focus on students and then on teachers). However, in this focus on the human, there is a danger of feeding the epistemological error of taking the individual as the unit of learning. What a socio-ecological perspective on mathematics education proposes, is a shift away from the individual as the locus of concern. Rather, what comes to the fore is community and political, ethical and ecological contexts.

There are many alternative sources of the idea of a de-centreing of human concerns, for instance, in post-humanist thinking (Wolfe, 2020). This article is not proposing socio-ecological practices as replacing or supplanting other perspectives, but rather as conjoining. One example of a study, which exemplifies this shift in what gets centred, is a project that took place in the Atoyac River region in Mexico (Solares-Rojas, et al., 2022). The project was a collaboration across scientists, teacher educators, teachers and community groups, aimed at curriculum innovation. However, what was at the centre of the project was the river itself. The Atoyac is highly polluted and the curriculum intervention focused on the past, present and possible futures for the river. Curriculum subjects (including mathematics) were in service to the work on the river and, particularly in the future focused work, individual actions were aimed at improving the state of the river.

2.4. A dialogic ethics

This section draws on ideas which are set out in more detail in Barwell, Boylan and Coles (2022). If we aim to work against the epistemological error that Bateson

(1972) points to, then our epistemology must concern relationships, and relationships get us in to questions of ethics (Abtahi et al., 2017; Boylan, 2016).

Bakhtin proposes that we think about ethics in terms of answerability or answerable acts, which he defines as follows: "An answerable act or deed is precisely that act which is performed on the basis of an acknowledgment of my obligative (ought-to-be) uniqueness" (1993, p. 42). I act ethically if I act on the basis of an acknowledgement of my unique obligations. A socio-ecological perspective argues that each of us has an obligation towards the socio-ecological health of the planet. In other words, the living world demands answerability from each one of us, in our actions as well as our words (Varela, 1999).

As we argue in Barwell, Boylan and Coles (2022), and drawing on Murray (2000), answerability can be seen as a complementary notion to Levinas's "call to responsibility" (p. 134). For Levinas (2011), it is through recognition by an Other, through responsibility, that we come to recognise ourselves as a subject. That Other might be another human or some other, living or non-living, part of the world. We answer the world, in acknowledging the uniqueness of our potential, and we recognise others for the uniqueness of theirs. And it is through *being* recognised by others that we gain the capacity for answering ourselves. A teacher educator may be able to act as such an "other" for prospective teachers, supporting their capacity for answering the needs their perceive in the world.

3. Socio-ecology and mathematics teacher education

Having set out, in broad terms, what is meant by a socio-ecological practice, this article now considers how these practices might be applied to mathematics teacher education and, in particular, the practices of mathematics teacher educators (MTEs) and the relationship between MTEs and prospective teachers. A dilemma in England (in 2023) arises, for any MTE wanting to adopt the kinds of practices alluded to above, because the current school curriculum has little space for considering socio-ecological questions, such as climate justice. So, MTEs are in the position of balancing the need to prepare prospective teachers to be able to take up roles in schools as they are now, with the need or desire (where it exists) to prompt reflection on how the teaching of mathematics might be part of a new social contract for education. One way through this dilemma comes from a distinction drawn by Wolfe (2020), writing about posthumanism, who counsels that we pay attention, not just to *what* we do, but *how* we do it. These two questions frame this section – the what (i.e., the content) and the how (i.e., the way we engage with that content), of a socio-ecological mathematics teacher education. In relation to both questions, I draw on my experiences of teacher education at the University of Bristol and consider, "What should we continue doing? What should we abandon? What needs to be creatively invented afresh?" (UNESCO, 2021, p. 2). Links are made to the 4 practices (2.1-2.4) described above. It will become apparent that practices 2.1 and 2.3 relate more to the "what" and 2.2 and 2.4 more to the "how". My main argument focuses on ethics (2.4), hence most space is given to the "how".

3.1. The "what" of a socio-ecological mathematics teacher education

In terms of the "what" of mathematics teacher education, and thinking about what gets centred (2.3), a socio-ecological practice might suggest supporting prospective teachers to be able to work in cross-curricular groups, because socio-ecological issues and challenges cross disciplines. It might mean working on how mathematics is used to model climate change, to predict and to communicate (considering how mathematics is involved in human relations). It might mean placing socio-ecological issues at the centre of teaching (2.3), for instance, projects studying changes in air pollution around a school (recognising that nature is not static). None of these things are easy to do but they seem to follow, fairly directly, from an awareness that nature is not a fixed background to the concerns of education (2.1) and from bringing focus to relations, not individuals (2.2). Examples of where such work on the "what" has taken place, in relation to mathematics teacher education, include, Savard's (2017) research on implementing an inquiry-based learning situation in science and mathematics at elementary school. The focus of this project was on "waste" and one conclusion was that teachers found it hard to integrate mathematics into the interdisciplinary project, despite many opportunities. A similar finding could be interpreted in Solares-Rojas et al. (2022), where mathematics played a small role in a rich inter-disciplinary project at primary level.

At the University of Bristol, since 2015, there has been a project to encourage and support prospective teachers to bring global issues into their teaching. On the secondary mathematics course for prospective teachers, the teachers have to complete a master's assignment in which they plan and teach a sequence of lessons, including one lesson that addresses a global issue. A group of teachers (supported by their University tutors, of whom I was one) wrote up some of the tasks created and trialled, as part of this assignment (Brown, Coles, Helliwell, et al., 2021, Brown, Coles, Hayward, et al., 2021). These tasks used contexts such as deforestation, Covid spread, gender inequality, in teaching a standard mathematics curriculum (2.3). The change in the "what" of the mathematics teacher education curriculum, which prompted this work, was bringing in a global challenge element to a master's level assessment.

One issue with work such as that taking place at Bristol, is that the National Curriculum in England has little space for addressing issues of global challenges. Hence, when prospective teachers take up positions in school, we find, consistently, that the space to continue bringing global issues into their teaching is limited and any activities done have a one-off feel (Coles & Helliwell, 2023). Indeed, as MTEs on the Bristol course, we also feel the extent of our focus on global challenges is limited, given the context for which we need to prepare prospective teachers (and an increasingly centralised curriculum for initial teacher education in England).

Another aspect of the "what" of mathematics teacher education, which may need to shift, is the way in which mathematics is framed and engaged with. To make meaningful connections to socio-ecological issues, teachers' and pupils' relationships with mathematics may need to evolve towards a recognition of the way that, for example: any mathematical truth is contingent on assumptions;

mathematics is not value-free; and, there are contingent human decisions behind mathematical conventions and definitions. Even in a constrained curriculum space, work on such awarenesses is possible. Something as simple as working on counting (or multiplication tables) in a number base which is not 10, can provoke a new awareness about the arbitrariness of the number naming system.

In terms of mathematics curriculum change (which might then provoke a change in the "what" of mathematics teacher education), a UK-wide, student-led group "Teach the Future" commissioned a set of "re-imaginings" of the National Curriculum. The proposal for the mathematics curriculum followed the organisation of an undergraduate course on Mathematics for Sustainability (Roe et al., 2018), in adopting the headings: Measuring, Changing, Mapping, Risking, Deciding. The proposals include a lessening of the emphasis on number work, to make space for introductory work on systems theory, economics and mathematical modelling, alongside a greater emphasis on data literacy. Were such a change to take place, we imagine a radical overhaul of mathematics teacher education in England would be necessary, to prepare teachers to teach modelling, for example.

This section has reviewed, briefly, some possibilities for change in the "what" of teacher education. However, no matter what the curriculum context of the work of a MTE, considering the "how" of mathematics teacher education is always possible. This is the focus of the next section.

3.2. The "how" of a socio-ecological mathematics teacher education

"How" MTEs go about teacher education is something which can potentially be changed immediately, towards a more socio-ecological practice, without needing to wait for wider curriculum or societal change – and which might even make some of those wider changes more likely. In relation to the four principles of a socio-ecological approach described above, it is the fourth one, a dialogic ethics, that I have found most relevant to the "how" of the relationships between MTEs and prospective teachers (and, in turn, prospective teachers and their students). From a dialogic perspective, the key question is, what might a relationship look like in which both MTEs and prospective teachers recognise each other, and in a manner that supports answerability (i.e., acts which are answerable to the living world) (2.4)?

If the relationship between MTEs and prospective teachers is to evolve into one that supports an on-going connection of mathematics to sustainability and justice, there is a need for this relationship to allow prospective teachers to re-imagine their own relations to schooling (including the students they teach). Prospective teachers and MTEs may have to support each other in working against the epistemological error (2.2) of taking individuality as the seat of learning and survival.

The relationship of a MTE and teacher, therefore, potentially needs to allow and provoke change in epistemological outlook. The MTE is then placed in a paradoxical position of wanting to engage in a particular kind of relationship with prospective teachers, when, by the fact of it being a relationship, they have no direct

control over how those relationships evolve. And here we are at the heart of the epistemological shift proposed by a socio-ecological perspective (2.2). A transformative relationship is not one that can be controlled or mandated from the perspective of one individual. So, what is it possible to do, as a MTE?

In addressing this question, one consideration is the kind of communications that can transpire between a MTE and prospective teacher (recognising that, in adopting this focus, nature is being taken as a fixed background (2.1)). I have suggested elsewhere (Coles, 2020) that communications in a group (or pair) have an *organisation*, which is the abstract set of relations determining what kinds of things are said, by whom, and when. The organisation of the communications in any setting evolves and changes and can be observed via the presence of patterns or social norms. In other words, a social norm (or socio-mathematical norm) in a group is an expression of its organisation. And part of any organisation of communication is a set of boundaries around what is acceptable (who is allowed to speak when and about what). Boundaries can of course be transgressed – establishing new forms of organisation. However, in a classroom setting, or with a group of prospective teachers, boundaries might be relatively stable. Boundaries tend to be established more or less unconsciously and it is clearly not the case that stating a boundary brings it into being. For example, prospective teachers may say to a class that they want no talking when they are talking, but the organisation of communication that transpires with the class may be quite different. Nonetheless, some communications do have a particular role in establishing boundaries, and these are "meta-communications" (Coles, 2020). A meta-communication is a communication about the communications taking place, in other words, a meta-communication is a communication about the organisation of communications.

A key element to the overall argument of this article is that a dialogic ethics, within mathematics teacher education, is helped by an organisation of communication, such that a MTE adopts a "meta-perspective" on their relationships with prospective teachers, commenting *about* this relationship, rather than on any intended or proposed change in an individual. (And, in turn, prospective teachers may adopt a "meta-perspective" with their students, commenting *about* their students' engagement with mathematics.) To make this argument, four practices on the Bristol teacher education course are described, below, in which a meta-perspective is evident and which support the focus of the MTE to be on the learning and awareness of the prospective teacher. These practices were largely established by Laurinda Brown, who set up a course structure in the 1990s that is recognisably the same now. Various aspects of the course that are touched on below have been written about in the past (Brown et al., 2020, Brown, Brown, et al., 2021). For each practice, one paragraph offers a description and a second paragraph draws out the "meta" aspects of the practice. In the following section, these "meta-practices" are related to a dialogic ethics.

1) Mini-teaching: before the start of the initial teacher education course, prospective teachers are told to prepare something (non-mathematical) to teach to a "tutor group" (of around 10 other prospective teachers). On the second day of the course, we spend time with each person teaching the others. A strict 10-minute

time-limit is imposed (i.e., they need to fill any space that may be left if they finish early and cannot carry on beyond the time). After each "mini-teaching", the others reflect back, to the one teaching, what they learnt, what helped their learning and anything that got in the way. The "teacher" takes their own notes and, at the end of everyone's mini-teaching, each person is invited to distil one (or more) key action-targets for them in their teaching.

The explicit aim of the mini-teachings is to establish, from the very start, the cycle that will continue through the course, of teaching a lesson, getting feedback, and then identifying an action-target for your next teaching (i.e., something you will do). As MTEs, we recognise prospective teachers as "teacher", from the outset, and establish a safe space in which they can inhabit what may be a new identity. We are not particularly concerned with offering specific feedback about teaching, but rather our (meta) focus is on the process of prospective teachers' learning about teaching.

2) Subject workshops: MTEs offer a series of workshops in the early weeks of the course, on mathematical content, such as "Geometry", on mathematical processes, such as "Proof" and on more generic teaching issues, such as "Assessment". While there is no set structure to the workshops, the aims are to offer prospective teachers experience of a range of ways of working, not for them to copy in their classrooms, but for them to reflect on in terms of what helped their learning. As soon as prospective teachers have some experience in schools, workshops draw on that experience. A common feature of all workshops is that they have a "meta" focus, alongside their more substantive focus. For example, in a session called the "4- minute workshop", prospective teachers have 15, four-minute tasks to do in pairs (changing pair each task). Some tasks may take less than four minutes and prospective teachers are told they need to ask their own extension question, in that case. As they move from one task to the other, the teachers are invited to reflect on what was being assessed, in the task, their own reaction to the task, and any reflections on working in a pair.

Subject workshops offer an opportunity to work with prospective teachers at multiple layers. There is always a school mathematics curriculum content (e.g., in the Geometry workshop, we use tasks involving 3-dimensions, such as sphere packing) and, there is a focus on issues in teaching and learning that content, e.g., through reflecting on the different experiences prospective teachers have of the workshop. As MTEs we hope to expose the teachers to the fact that, across the group, there will be different reactions to the same task and a need for attention to the different interpretations others may have. As well as a content and didactical focus, there is always a third (meta) layer, of a focus on an aspect of more general pedagogy (e.g., in the Number workshop, on different forms of teacher questioning). We ask prospective teachers to attend to these multiple aspects, at the same time.

3) Teaching issues discussions: the course structure of University teacher education courses in England varies from provider to provider, however, there will always be an interweaving of time in University and time on placement in school. At

Bristol, whenever prospective teachers return to University from a time spent in school, in the first session, MTEs organise them into groups of three, to discuss any issues arising from their time in school (for 30-45 minutes). The 3-way discussions then expand to a whole group discussion of one or two issues that were unresolved (for around 30 minutes).

As MTEs, when we observe the prospective teachers in their 3-way discussions, we often remark "why would we want them to do anything different, when they return from school!". The experience of school placements is so rich, and also happens with such intensity and often with little time to reflect deeply, that the space to dwell in experiences seems invaluable. What emerges from the group as issues for wider discussion is always different. As MTEs, in facilitating such conversations, we aim to identify an "issue" and then share a range of "strategies", i.e., things you could do, which might support development against the issue. An example might be the issue of "how do I know what the students know?", and strategies might include a range of assessment techniques.

4) Lesson de-brief conversations: MTEs on the Bristol course go in to school to observe prospective teachers at least three times over the 10-month course. Observations are always done jointly with a school-based mentor and there is always a 3-way de-brief conversation immediately afterwards. MTEs from Bristol have written in more detail about practices within the de-brief conversation (Brown et al., 2020). The first question to the prospective teacher is to identify something which went well, or not so well, or something they would have done differently if they had their time again. When the conversations run smoothly, the prospective teacher identifies a moment from the lesson which carries some emotional hue (comfort/discomfort). These are likely to be moments where either something valuable happened which can be identified to try to make it happen more often, or moments where there is a desire for change.

One awareness we share, as MTEs, is that prospective teachers are likely to be able to make most progress in their teaching if they focus on issues that are already in their awareness. Hence, in our de-briefing, we are not concerned with sharing our own judgments on the lesson, but adopt the meta-perspective, of trying to support a process of the prospective teacher identifying an issue of salience to them, and then working on strategies which might help them work on that issue. An important part of the process is the on-going relationship of the MTE with the school-based mentor (which may well be longer lasting than the 1-year course of the prospective teachers). Part of the MTE's role during the lesson itself, we view as working with the mentor on the mathematics of the lesson (e.g., exploring alternatives, or doing the questions being asked of students). The MTE focus is primarily on relationships, their own relationship with the mentor, and checking that the relationship between prospective teacher and mentor is working well enough to support learning and development.

3.3. Reflecting on the "how"

The four practices described above make no mention of socio-ecological issues. They are not concerned with the "what" of a socio-ecological teacher education. However, in relation to socio-ecological practices, it is hopefully apparent that, in each case, there is a move to a meta-perspective, on the part of the MTE, meaning that the content of communication is led by the prospective teacher. As MTEs, we can act to consciously create an organisation around communications with prospective teachers, such that *their* concerns are at the fore. Our concerns are with how prospective teachers are dealing with those concerns and how they are working on the issues they identify. A meta-perspective, when it works well, gives space for MTE recognition *of* the prospective teacher. In the recognition by an Other (in this case, a MTE), according to Levinas (2011), the prospective teacher has the opportunity to recognise themselves. And, in recognising themselves, they have the possibility of recognising their answerability – their capacity to respond, to take responsibility, in relation to the issues that concern them. In other words, taking a meta-perspective as a MTE could be seen as an act consistent with a dialogic ethics.

The "how" of socio-ecological practices of mathematics teacher education, therefore, of necessity does not relate explicitly to issues such as climate justice. However, in working towards a dialogic ethics, MTEs might hope to create the space for prospective teachers to keep in touch with those issues (both in their teaching and in wider society) about which they feel most strongly, through adopting a meta-practice of communications with those teachers.

The course at Bristol was not set up along socio-ecological lines. Yet, MTEs working on the course have remarked that through all the changes in national curricula and re-organisations of teacher education in England during that time, the basic principles of the course have remained stable. We believe this is a result of the meta-perspective taken, so that as the context changes, prospective teachers are able to bring whatever concerns them, and are able to work on their concerns, in University sessions. I have only recently come to recognise this feature of the course as describable in terms of a dialogic ethics, and to view a dialogic ethics as central to socio-ecological practices. In relation to UNESCO's questions, posed at the start of the article, the meta-perspective of a MTE is something, at the University of Bristol, that I hope we continue doing, during any (hoped for) movement towards a new social contract for education.

4. Conclusion

This article aimed to set out some initial thinking about a socio-ecological practice of mathematics teacher education. The article proposed four sets of practices, in keeping with a socio-ecological perspective, which are: (1) not taking nature as a fixed background; (2) moving away from the error of taking the individual as the unit of learning; (3) questioning what gets centred in our work; (4) a dialogic ethics. Both the "what" and the "how" of mathematics teacher education were then considered, drawing in particular on my experiences teaching on a teacher education course at the University of Bristol. The "what" of mathematics teacher education

particularly concerns (1) and (3) above. It is within the content of a mathematics teacher education course that we might be able to integrate the awareness of the interconnection of socio-political and ecological questions, for example through work on mathematical modelling. And it is in relation to the "what" that we might be able to question what is centred in a teacher education course and, for instance, move to centre socio-ecological issues, such as air pollution.

The "how" of mathematics teacher education particularly relates to practices (2) and (4). A dialogic ethics is not something that, I believe, can ever be said to be "done". Adopting a dialogic ethics is a process – we can only be working towards, or away from a dialogic ethics, we never arrive. The article argued that a dialogic ethics is made possible by the meta-perspective of a MTE and brief details were offered of four practices of a MTE, which relate to taking a meta-focus. The meta-perspective of the MTE, and the opening of the space of relationship to the concerns of the prospective teacher, involves a form of expansion away from the individual. A dialogic ethics does not start from the assumption of pre-existing selves, who come into communication and dialogue. Rather, in a dialogic ethics, it is the relationship which has primacy. The extraordinary insight in Levinas' (2011) views on ethics, is that we become a self through relationship, and through being recognised. Our relationships are primary – and recognising this reality is equivalent to recognising the epistemological error of taking the individual as the unit of survival and learning (2).

At the time of writing in England, schools are in crisis, through a lack of funding; Universities are in little better shape. Teachers and University staff are both going on strike about concerns over their working conditions. The curriculum is geared towards memorisation of facts and "direct instruction" approaches are being promoted across the country, in the belief that teachers will serve their students best through offering clear examples for those students to copy. The scenario could hardly seem further away from any attention to socio-ecological practices and a time of "creatively inventing afresh". And yet, I remain hopeful that a change is imminent. The contradictions of the current dispensation feel like they are being exposed. Groups such as Teach the Future signal the energy that exists in some communities, for change. Our experience on the Bristol teacher education course is that prospective teachers are increasingly concerned to bring socio-ecological issues into their teaching. One image I have of why thinking about socio-ecological practices is important now (as well as in the future) is that we are developing the ground of a curriculum in waiting. The distinction between the what and the how of teacher education is relevant here. In contexts where the "what" is subject to political control or interference, it is still possible to work on the "how". Every action we take which moves towards a dialogic ethics, in our relationships with prospective mathematics teachers, is one that prepares the future for change.

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Hacia una práctica socioecológica de la formación del profesorado de matemáticas

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Este artículo teórico es una respuesta al llamamiento de la UNESCO en favor de un nuevo contrato social para la educación en el contexto de la formación de profesores de matemáticas. En el artículo se exponen cuatro principios en los que se basan las prácticas "socioecológicas" en la educación matemática: (1) no tomar la naturaleza como un trasfondo fijo de preocupaciones (como educadores de matemáticas, generalmente hemos asumido, por ejemplo, que no es necesario considerar la calidad del aire que los estudiantes y maestros respiran, a medida que avanzamos en nuestra investigación tales suposiciones son cada vez más difíciles de mantener); (2) evitar el error epistemológico de tomar al individuo como unidad de aprendizaje (diversas tradiciones de pensamiento convergen en la idea de que son las relaciones, y no los individuos, las que evolucionan, sobreviven y aprenden); (3) cuestionar lo que está centrado en nuestro trabajo (se ofrece un ejemplo de un proyecto de investigación en el que un río está en el centro de las preocupaciones); (4) avanzar hacia una ética dialógica (una idea clave es que es a través del reconocimiento por parte de otro, que llegamos a reconocernos a nosotros mismos y nuestra responsabilidad única). El artículo considera el "qué" y el "cómo" de la formación del profesorado de matemáticas desde esta perspectiva socioecológica. El "qué" incluye el contenido de la formación docente. Un ejemplo de una práctica socioecológica relacionada con el "qué" de la formación del profesorado de matemáticas es el trabajo realizado con un grupo activista liderado por estudiantes Teach the Future, para reimaginar el Currículo Nacional en Inglaterra. El "cómo" se refiere a la manera en que se lleva a cabo la enseñanza, por ejemplo, los tipos de comunicación que se producen entre un formador de profesores de matemáticas y un futuro profesor. Se ofrecen ejemplos del curso de formación de profesores de la Universidad de Bristol, en Inglaterra, en el que los formadores de profesores de matemáticas estructuran sesiones y prácticas para adoptar una perspectiva "meta". En otras palabras, la práctica en Bristol consiste en permitir que los futuros profesores traigan sus propias preocupaciones y observaciones a las sesiones, que constituyen la base de lo que se hace. El formador de profesores de matemáticas adopta una metaperspectiva y se responsabiliza de la forma en que se discuten y trabajan las experiencias, no del contenido de las mismas. En cuanto al "cómo" de la formación del profesorado, un formador de profesores de matemáticas que adopte una "metaperspectiva" en las relaciones con los futuros profesores, es coherente con una ética dialógica. Una metaperspectiva hace que se preste atención al potencial para reconocer a los futuros profesores como "profesores" desde el comienzo del curso de formación. En contextos en los que el "qué" de la formación del profesorado de matemáticas está políticamente muy limitado, el "cómo" de las prácticas socioecológicas aún puede ser posible de promulgar.