TOWARDS A SOCIO-ECOLOGICAL PERSPECTIVE OF MATHEMATICS EDUCATION

Alf Coles, Kate le Roux, Armando Solares

University of Bristol, University of Cape Town, CINVESTAV

In this theoretical research report we propose a socio-ecological perspective, as relevant for research in mathematics education that takes account of our complex, precarious present and imagined future, while recognising its historical roots. We discuss briefly work that considers the social, political and ecological, and build from this scholarship. A 'socio-ecological' perspective considers the social and ecological as entangled, and mathematics (education) as both shaping and shaped by these entanglements. This is a mathematics (education) that gains meaning from questions that emerge in socio-ecological relations. We ground our theoretical argument using a project located in a community living in a polluted region of Mexico, where a river is central to the questions motivating community activism and our research.

RATIONALE

Contemporary world events offer stark evidence of the inseparability of social, ecological, health, spatial and political issues such as: climate change effects related to water, heat, biodiversity loss; health pandemics; poverty; inequality; unemployment; migration; totalitarianism and loss of voice. This is a rapidly changing world characterised by complexity, uncertainty, vulnerability, movement, and informality, with the pace of change outstripping our knowledge of this world. These events challenge the mathematics education community to consider, in Latour's (2004) words, "Are we not like those mechanical toys that endlessly make the same gesture when everything else has changed around them?" (p.225). We conceptualise mathematics education as making "gestures" in the form of recontextualised knowledge, curriculum organisations, textbooks, professional development opportunities, and anything that becomes visible in the context of teaching and learning. We are prompted by Latour to ask: What might be the "gesture" of a recontextualised mathematics? We ask this in a context in which a supposedly neutral and universal mathematics, valued for its descriptive, categorical and predictive possibilities, has, in action, in science and technology, come to format the world as 'calculable' (Mbembe, 2021; Skovsmose, 2011). What might be some alternative "gestures" of a mathematics education that is commonly and unquestioningly considered a necessary individual and social 'good'?

In what follows, we propose a socio-ecological perspective as one response to the aforementioned challenges faced by mathematics education, taking the social in 'socio' as inherently political. We do not see the socio-ecological as replacing other perspectives, but rather as complementing and building on them to offer insights that recognise the entanglement of the social and ecological, and the role of mathematics

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(education) therein. To ground our theoretical argument in this report, we use a project situated in Tlaxcala State, Mexico, in which the first and third authors participated and alongside which our thinking about the socio-ecological has developed. We describe this context first, acknowledging that any such description cannot capture its complexity and history. We then discuss briefly existing mathematics education scholarship relevant for our consideration of the social, political and ecological. Finally, we describe our proposed perspective and some possible future directions.

THE ATOYAC RIVER PROJECT

The Atoyac River in Mexico is the third most polluted in the country. From a visit to the region by the first and third authors, it is clear the river no longer supports animal life. Coloured dyes from a textile factory and heavy metals from a car parts factory (both of them internationally owned) are regular discharges into the river. The toxic smell is noticeable over 1km away, in a primary school playground, and the significant negative health effects on the local population, such as child leukemia, are documented. From having a central role in the life of the community and its rituals, the river is now rarely visited. A network was instigated decades ago, by community members living near the river, and including non-governmental organisations, school teachers and academic scientists from a range of disciplines, in order to respond to the pollution issue. The first and third authors of this report were invited (having won a grant from the UK's Global Challenges Research Fund, EP/T003545/1) to bring an education perspective to the network. The initial research question they were challenged with was, how the Mexican primary curriculum, including the mathematics therein, might become "relevant" in such contexts of complexity, vulnerability, and marginalisation. Over the course of an academic year, the primary school children involved in the project engaged in many activities relating to the pollution of the river. Mathematics was not always present; one task where it was involved comparing data, looking at the biodiversity of the region today and comparing this to the biodiversity remembered by the children's parents, grandparents and other elders in the community.

This curriculum project (henceforth the *Atoyac River project*) is productive for thinking about the socio-ecological, for it is *the river* that had been studied for decades, that is central to the context. It is the dramatic changes in the river that provoked changes in lifestyles in the region (e.g., a disappearance of fishing and recreation in the river). It is the river which is at the centre of the community's social activism ("Coordinadora por un Atoyac Con Vida" [Coordinator for a Living Atoyac] and "Centro Fray Julián Garcés Derechos Humanos y Desarrollo Local", [Fray Julián Garcés Human Rights and Local Development centre]). And it is around the river that the network (and the questions it asks) was conceived. We return to this project through the next section in a hypothetical way, to illustrate how it could be approached from different perspectives, and again in a concluding section, where we describe the project's influence on how we have come to think about the socio-ecological and the questions it provokes.

TRENDS IN RESEARCH IN MATHEMATICS EDUCATION RELATING TO SOCIAL, POLITICAL AND ECOLOGICAL CONCERNS

The past two decades have seen a growth in a *socio-political perspective* of mathematics education (following Gutiérrez, 2013; Valero, 2004). Using notions of knowledge, power, and subjectivity, this perspective conceptualises mathematics and mathematics education as historical, social, and political practices. Broadly, it is concerned with understanding how mathematics (education) might (re)produce wider practices and structures of inequality, and with acting towards a more socially just and ethical world. In this section we discuss particular named areas of the work within this perspective, as relevant for our focus on the socio-ecological, noting the constraints on space, and that the definitions of research areas and their relations are contested.

Critical mathematics education (CME), is united by particular concerns, commonly raised from within the dominant Euro-modern knowledge and education structures (Vithal & Skovsmose, 1997). Firstly, how mathematics (re)produces, or 'writes', the world through action in, for example, science, technology, economics. And also how mathematics education (re)produces particular subjectivities and knowledges. Secondly, CME is concerned with mathematics (education) for understanding, or 'reading' the world, aspiring to the possibilities of (re)writing for a more democratic, socially just world (see, for example, the edited volumes: Alrø, Ravn, & Valero, 2010; Andersson & Barwell, 2021). CME's view of the role of mathematics (education) in society informs perspectives variously named as *mathematics for social justice/peace/democracy*. In the Atoyac River project, taking a CME approach would suggest using school mathematics (education) to understand the social injustices of the pollution to the river, in terms of health outcomes, and to provoke action for change.

More recently, CME scholarship has demonstrated the potential of mathematics (education) to write and read the contemporary ecological condition of the world, or 'climate change' (e.g. Hauge & Barwell, 2017; the edited volume by Coles et al., 2013), in what might be called a *mathematics for environmental sustainability*. If following such an approach, the Atoyac River project would focus on a mathematical understanding the ecological health and future of the river itself, again accompanied by action against the ecological injustices.

Socio-critical modelling, described as an "emancipatory perspective" (Kaiser & Sririman, 2006, p.304) of mathematical modelling for a critical understanding of the world, has strong links to CME. Educationally, socio-critical modelling centers "students' ability to be critical modelers and [to] recognize their power", rather than their mathematical understanding and skills (Abassian et al., 2020, p.61). For the Atoyac River project, such an approach would foreground the social action that could follow a critical investigation of the river and its pollution and the modelling of trends.

Other areas of socio-political mathematics education have thought from the 'outside' of the dominant canon and structures (Vithal & Skovsmose, 1997), and have commonly been shaped by the marginalised positions in which they emerge. For

example, *ethnomathematics* challenges dominant narratives of the history of mathematics, and identifies what are considered culturally and socially embedded ways of thinking and acting mathematically that are decentred by dominant mathematics (education) (e.g. Powell & Frankenstein, 1997; Rosa et al., 2017). In its naming, *ethno*mathematics specifically focuses on the practices of social groups, with the ecological a context in which human activities are developed, for example, land measurement practices. An ethnomathematics perspective in the Atoyac River project would involve attention to the past and present mathematical knowledge and practices used by the community, located in the context of the river.

Scholarship on *indigenous ways of knowing* commonly foregrounds the ways of knowing, acting, being and using language of variously named indigenous communities that have been traditional marginalised in dominant mathematics (education) (e.g. the edited volume by Nicol et al., 2020). As with ethnomathematics, the very nature of relations in these contexts signals the presence of the ecological. In the Atoyac River project this would mean attending to ways of the community, which could include the very manner in which human-river relations have been enacted.

Learnings from ethnomathematics and indigenous ways of knowing are used to inform what is called *culturally responsive mathematics education*. With their focus on groups marginalised by coloniality, neoliberal globalisation, and so on, all three are presented as ways to 'decolonise' mathematics education. However, *decolonial and antiracist perspectives* of mathematics education specifically draw from traditions of post/decolonial and/or critical race theory to: (a) understand and surface the co-constitution of racial (and related) difference in the entanglement of mathematics (education) in historical processes; and (b) promote an active process of becoming of mathematics knowledges and knowers (e.g. Martin, 2019; Swanson & Chronaki, 2017). In the Atoyac River project, the focus would be the role of mathematics (education) in historical and contemporary processes that (re)produce hierarchical difference and by which the region has come to be vulnerable and marginalised.

TOWARDS A SOCIO-ECOLOGICAL PERSPECTIVE

The brief discussion in the previous section suggests that, within a socio-political perspective of mathematics education, there is scholarship that takes account of the environment, or of ecological issues. But, at the same time, it appears that the ecological may be taken as context in which peoples and mathematics (education) act, rather than being strongly theorised in itself, or in relation to other actors. A move towards greater acknowledgment of the ecological is, however, discernible in the recent work of some scholars who supplement the aforementioned approaches using theoretical traditions, again, 'outside' of mathematics education such as *(eco)feminist, ecocritical, ecojustice, and posthumanist* ideas (e.g. Coles, 2017; Gutiérrez, 2017; Khan, 2020; Wolfmeyer, Lupinacci, & Chesky, 2018).

It is in these recent moves in the field that we locate our argument for a *socio-ecological* perspective of mathematics education. Specifically, we conceptualise

the past, present and future world as entanglements and interdependencies between the social and ecological, and consider the role (or not) of multiple forms of mathematical knowing and being therein. Such a perspective recognises multiple actors in the constitution of the world, and hence the presence of the (un)quantifiable within socio-ecological contexts and challenges. Such as perspective may, at times, 'decentre' particular forms of mathematical knowing. Conscious that decentring mathematics might be read as counter-intuitive, in the context of a mathematics education conference, we stress that we are proposing a shift towards thinking about mathematics (education) as gaining meaning through relations between actors, which include the human and non-human (e.g. the environment and mathematics itself). We view the perspective as a move to starting with questions, that is, the perspective is relevant when the questions we are asking, or concerns we carry, are themselves socio-ecological, for instance taking a river and its relations as the starting point of questions and of our research.

Also relevant to a socio-ecological perspective is the emergence of new materialisms (e.g. de Freitas & Sinclair, 2014; Appelby & Pennycook, 2017) which see technology, language and the natural world as actors within and besides the human. Such new materialisms lead, for us, into the kind of entangled view of the world that emerges through the socio-ecological. The socio-ecological allows us to inhabit the intersection of social constructs such as gender, class, language, and race *and* bodies, things, ecologies, space, in semiotic and material assemblages. How might our thinking respect, or engage with, the complexity of what we are thinking about (Bateson, 1972)?

The socio-ecological perspective, emerging from questions in the Atoyac River project that we have started to lay out in this section, has epistemological and ontological implications. We start to explicate these next, before discussing further questions prompted by our thinking about the socio-ecological.

Epistemology and ontology of a socio-ecological perspective

From several theoretical positions, a relational ontology is being proposed (e.g. de Freitas & Sinclair, 2014) and such relationality is important also within a socio-ecological perspective. The entanglement of the social and ecological means, for instance, the entanglement of subject and object. Rather than thinking about an encounter as a meeting of two pre-existing entities, a relational ontology implies the view that it is through encounter that subject and object inhabit an identity (for the duration of that encounter). Rather than asking, e.g., "who acts?" (a question which presupposes an already existing subject) a more relational question would be, "how is it that such a subject is able to act in this way" (Benjamin, 2015, p.87). This second question invites attention to the always-already existing webs of relations that allow action in the first place. And, from a socio-ecological perspective, this web of relations include culture, politics, ecology, history. Subjectivity is an after-effect of the socio-ecological relations that allow its emergence, not a pre-condition of those relations.

In terms of epistemology, a certain humility is required. Others' ways of knowing may be radically different to our own and yet equally valid. Furthermore, there are implications for the kinds of knowing that are significant. From a socio-ecological perspective, what is important is to develop wisdom about the complexity of inter-relationships in which we are enmeshed, and less valued will be instrumental knowledge of apparently linear cause and effect relations. Taking a wider systemic view, all relations end up in loops that cycle and become iterative (Bateson, 1972). Thus, some "gestures" (Latour, 2004, p.225) of mathematics education research from a socio-ecological perspective might include: listening to marginalised actors and the questions they provoke; attending to the ecological precarity of communities and adaptations being made to issues such as pollution or climate change; seeking double or multiple descriptions; paying attention to the different scales at which actions take place; questioning the spatial imagination that constrains thinking about a relationship; questioning the role of mathematics in conceptulisations of the ecological.

Towards new questions

Having articulated some of the philosophical ideas we have been led to, we now reflect on the kinds of questions a socio-ecological perspective might prompt us to ask, if we take seriously a relational ontology and an epistemology that is sensitive to ecologies. We offer a diverse set, starting with the Atoyac River and becoming more general.

How is the river remembered? How do pollution levels vary over time and what is the impact? What is the route back to a healthy river? How are ecological precarities experienced differently and what inequalities does this expose? What is the relationship between climate change and inequality? How might reparations for loss and damage through climate change be calculated fairly? What is the role of disciplinary knowledge and thinking, in relation to inter-disciplinary competencies? What mathematical fields (e.g., systems theory, non-linear dynamics) are relevant to socio-ecological questions? What kinds of curriculum organisation allow a centring of non-human, ecological concerns? What mathematics is done by ecologies?

We offer these questions, conscious they are disparate, as provocations and in the hope that the theoretical work of this report will prompt others to become attuned to possible socio-ecological questions relevant to their own contexts.

THE ATOYAC RIVER AND A SOCIO-ECOLOGICAL PERSPECTIVE

We end this report with a final set of reflections on the Atoyac River project. Our thinking about the socio-ecological has developed alongside this research; at the time of starting the project, it was aligned with a socio-critical perspective on mathematical modelling (in part, drawing on the modelling expertise of the third author). What this meant was that social action was a central concern. A disturbing feature of the Atoyac context (that we believe is repeated in many other places) is a normalisation of illegal pollution. The river has been polluted for so long that primary school children (and some of their teachers) have never known it otherwise and hence it can appear as though an alternative future is not possible. There can seem to be an inevitability to

how the river is now, because it seems it has always been this way. There was a hope among many participants in the research that the work would spark action and a belief in the possibilities for different futures. What we have come to recognise is the centrality of the river, as described in section 2, not in any sense at the expense of social or political concerns, but rather as a focus for these concerns.

We are conscious of the possible objection that what we are describing is not properly mathematics education. However, and crucially, we want to argue that a socio-ecological perspective *is* relevant to mathematics education and that mathematics education needs to accommodate a perspective (not exclusively, but as a possibility) which re-imagines mathematics in a position which is not central to the problems it addresses, but is defined by its relationality, and might gain its relevance from questions that emerge in the socio-ecological. Indeed, in the Atoyac River project, the community subscribes to a complex and entangled understanding of social, economic, historical, cultural, biological and human and non-human health and rights issues. As researchers in this project, we have been provoked to reimagine our thinking about the gestures of mathematics education and mathematics in this socio-ecological context.

We are conscious we have only made a start at setting out a socio-ecological perspective of mathematics education; work we hope to continue and encourage others at PME to join. What we have offered in this report is, in part, our own process of finding ways to engage, to listen, in contexts that can sometimes feel overwhelming.

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