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TROUBLING THE AIMS OF MATHEMATICS EDUCATION IN THE SOCIO-ECOLOGICAL

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We propose to engage in a critical examination of the aims of mathematics education in the socio-ecological by challenging some typical standard proposals that may emerge for fostering change and raising awareness concerning current multiple climate crises. The challenge comes not only from the (im)possibilities of connected educational configurations, but foremostly from the investigation of mathematics education as a cultural, political, and economic space of subjectivation in the Modern governing of populations and individuals. We argue that such type of systematic critique is important to understand the limits and promises of mathematics education and well-intentioned proposals for action that may emerge in the field. Without critique, research may risk contributing to a simple "green washing" of the curriculum and the practices of mathematics education.

A TYPICAL WELL-INTENTIONED PROPOSAL FOR CHANGE

As concerned mathematics educators, we are increasingly worried by the rapid progression of environmental degradation and the various alarming symptoms of climate change. In the face of these challenges, mathematics stands out as a crucial ally. Through the application of mathematical modeling, scientists can simulate climate systems and predict future changes with remarkable accuracy. These models help us understand the potential impacts of various environmental policies and human activities, guiding decision-makers towards sustainable practices. Statistical methods allow us to analyze vast amounts of climate data, identify patterns, and assess the effectiveness of mitigation and adaptation strategies. Mathematical optimization techniques can be used to develop efficient resource management plans, minimizing environmental impact while at the same time meeting human needs.

By integrating environmental issues into all types of mathematics curricula, educators can contribute to equip students with the knowledge, critical thinking and problem-solving skills necessary to apply mathematics and address these global challenges. This approach not only enhances students' mathematical proficiency but also fosters a sense of responsibility and empowerment, inspiring them to contribute to the creation of a sustainable future, showing that mathematics is not just an abstract discipline but a vital tool in the urgent fight against climate change because it offers the analytical framework needed to understand its complexities and devise effective solutions.

It is thus imperative that the aims of mathematics education align with the OECD's and UN's Sustainable Development Goals, particularly SDG 4 (Quality Education) and SDG 13 (Climate Action). We must fundamentally rethink and reshape mathematics curricula to incorporate sustainability and environmental literacy. As a consequence, we should integrate real-world problems related to climate change directly into mathematics lessons, making the subject more relevant and engaging for students while simultaneously fostering a deeper understanding of global environmental challenges. For instance, lessons could include analyzing carbon footprints, calculating the impact of various energy sources or modeling population growth and its

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environmental consequences or else they could include the development of models for sustainable urban planning, optimize water usage in agriculture or predict the outcomes of different climate policies. Moreover, professional development for teachers should offer training to effectively integrate sustainability into teaching, to bring new technologies and to use new assessment methods. This includes understanding the latest research in climate science and environmental mathematics as well as learning how to foster a classroom environment that encourages socially-responsible thinking and innovation.

By transforming mathematics education in these ways, we can not only equip students with the technical skills needed to address climate change, but also cultivate a generation of informed, responsible, and proactive citizens. This aligns with a vision for education that promotes academic excellence while also developing skills and values necessary for a sustainable and equitable future. Through these changes, mathematics education can become a powerful driver of both personal and planetary well-being, helping to achieve the Sustainable Development Goals and securing a better future for all.

SKEPTICAL EDUCATIONAL OBJECTIONS

Wait, what? Really? From a skeptical educational point of view, a first set of objections to the sketched proposal above can be raised. While integrating climate change themes into mathematics education may seem like a just and promising endeavor, it is essential to critically examine the practical feasibility of this and similar proposals as well as considering whether overall similar initiatives may genuinely contribute to solving the ecological crises or simply serve as possibly empty symbolic gestures with no real environmental gain.

A first difficulty is that proposals such as the above seem to assume a one-size-fits-all approach, aligning with externally mandated guidelines like the UN's Sustainable Development Goals. However, not only do educational contexts vary widely across different regions and countries but also environmental challenges may be different in different areas and geographical situations. Second, a more fundamental difficulty is that the primary role of mathematics education has traditionally been and still is related to the development of students' mathematical knowledge, abilities and competencies. Some mathematics educators —or schools, parents, politicians, employers— would not be willing to divert too much focus from the mathematical core towards environmental themes which might dilute the rigor and depth needed for mathematics instruction of high quality.

Furthermore, mathematics teachers are trained in mathematics, not in environmental or climate science. Hence, a potential restructuring of mathematics education towards environmental goals places a significant and perhaps unfeasible burden on mathematics teachers. Professional development programs can help, but they require substantial investment in time and resources, which may not be feasible for all educational institutions, especially those already facing budget constraints. Indeed, expecting teachers to cultivate not just mathematical proficiency but also environmental topics and communicate a sense of responsibility for the environment may be overwhelming in the current circumstances, possibly leading to increased burnout and reduced effectiveness and well-being.

Moreover, there could be a risk that the overemphasis on mathematical modeling is more detrimental than beneficial in treating environmental issues. Indeed, mathematical models, while powerful tools,

are not infallible but come with assumptions, approximations and simplifications. Over-reliance on models without understanding their constraints could mislead students about the predictive power of mathematics. For example, climate models often involve simplifications of complex natural systems and are influenced by the quality and quantity of data available as well as by the assumptions made by scientists. Misunderstanding these factors can lead students to overestimate the precision and reliability of model predictions.

Hence, there is a risk that typical well-intentioned proposals to align mathematics education with environmental concerns could become superficial, focusing more on the appearance of addressing climate change rather than achieving meaningful outcomes.

CULTURAL-POLITICAL OBJECTIONS

A further critical stance can help us problematize the proposal above which exemplifies the usual way of responding to societal challenges in education, in general, and mathematics education, in particular. The proposal can be seen as an articulation of the existing "order of discourse" — in Foucault's terms — which frames what is perceived as familiar, research-based responses to new problems of practice. Indeed, resonances can be found between the proposal and reports with suggestions by international organizations such as the OECD (e.g., Nusche et al., 2024) which suggests rethinking STEM education to "get the foundations right". UNESCO (2024) emphasizes how climate change affects education — worsening results in mathematics achievement of affected populations — and how a shift towards social and emotional, and action-oriented learning should help mitigating climate change. The response from educators and agencies governing education appeal to a sense of urgency and to the necessity of action, and provide expert-based avenues to steer education in new directions.

As well intentioned and — most of the time — well-supported the responses may be, they mobilize a logic of educationalization of social problems (e.g., Tröhler, 2017): the characteristic of Modern education to be thought of as the most effective mechanism to solve different types of social challenges by regulating changes in the knowledge, cognitive capacities, moralities and behavior of populations and individuals. Educationalization leads to an overestimation of the role of education in solving complex, non-educational problems such as, for instance, global climate change. While education indeed may help in raising awareness, it is not a panacea. Comprehensive solutions to the ecological crises — an any other social problem, for that matter — require large coordinated efforts across multiple sectors, including policy, industry and communities. Expecting mathematics education alone to drive significant change may set unrealistic expectations and divert attention from other essential actions. In other words, orienting the formulation of the aims of mathematics education in what is perceived as a new time of socio-ecological crises with the logic of the proposal above may simply continue following the same Modern impulse. But if that logic has worked before — think for example the time of the Sputnik crises —, why not now?

We would argue that a stance that critically challenges the Modern impulse is worth mobilizing, given that what is identified as socio-ecological crises are a manifestation of how the cultural, economic and political project of Modernity with its impulse for the transformation, appropriation and exploitation of humans and not humans has overpassed what the planet can bear (e.g., Latour, 2017). Therefore, the stance that we adopt to trouble the aims of mathematics education in the socio-

ecological considers mathematics education as an important cultural-historical network of subjectivation practices in education. As argued in studies on the *cultural politics of mathematics education* (e.g., Ziols & Kirschgasler, 2024), mathematics as a subject of the school curriculum in Modern mass education has served not only the purposes of qualifications through the expansion of elements of mathematical knowledge, skills and competences, but also and inseparably the fabrication of types of subjectivities that embody central values, moralities, epistemic virtues and ways of conceiving of the world and the self (cf. Beccuti, 2024). Investigating how school mathematics knowledge and being are articulated is central in understanding the aims of mathematics education as a space to make culture, to create certain notions of nature, and to envision which functions people's mathematical qualifications are to play.

Also, the fact that mathematics education is studied in relation to the making of subjectivities renders both mathematics education and research as political (e.g., Kollosche, 2016). That is, power is being effected in and through these practices, as populations and individuals are governed, classified and ordered with respect to their coming closer (or not) to desired forms of knowing and being. In this sense, mathematics education instantiates power, resulting in the (re)production of multiple in(ex)clusions.

Thus, an exploration of the aims of mathematics education adopting this stance directs our attention to the ways in which mathematics education is materially and discursively articulated in different sites: not only in schools and classrooms, but also in the many other sites that make part of the distributed network of institutions and practices that support its cultural importance for producing mathematical subjectivation. Theoretically/methodologically, the exploration brings us to cultural studies, sociology and philosophy, to look for ways of unpacking how and in which conditions such subjectivation is effected, and to challenge its consequences.

CULTURAL-ECONOMIC OBJECTIONS

Thinking with Latour (2017), Valero (2023) has argued that the forms of subjectivity fostered in/through school mathematics education practices have historically been tied to Modern narratives of progress and development which now show to be an unsustainable project for the planet. Furthermore, the project of Modernity has also been associated with the endless expansion of capitalist forms of exploitation of both human and non-human resources. As Fraser (2023) pointed out, not only the mode of production of current neoliberal Capitalism concerns the mere act of endless material exploitation of nature, but also, since its Modern inception, tends to reproduce forms of subjectivation connected to a peculiar form of representation of nature itself. This fundamentally serves to sustain the perpetuation of its exploitation: nature is represented as an inert mass of exploitable and disposable objects, the ultimately inessential and inert "other" of humankind (*ibid.*).

If the cultural link through history between mathematics education and the project of Modern technoscientific progress and capitalism are inseparably linked in governing and producing types of people who are functional to the Modern capitalist order — even in its recent manifestations —, then mathematics education cannot really serve a function of safeguarding the planet or deterring its brutal continuous exploitation, as has been the case until now. Mathematics education in its current form — articulated aims and curricular and pedagogical organization — from the outset cannot be used to promote different forms of subjectivation that are more "socio-ecological aware", "planet-friendly"

or even less "planet-rescuing" force. And proposing more of the same type of mathematics education that has been contributing to the situation that we are at now may lead nowhere than to the worsening of the situation. We seem to be facing a type of "Catch-22" situation, confronting a central impasse for mathematics education: the desire of mathematics education to "maintaining and promoting Modern forms of mathematical subjectivation risks proclaiming a death sentence on the planet, since the planet cannot bear any further project of modernization" (Valero, 2023, p. 56) that mathematics education is designed to perform. Furthermore, and making clear Valero's argument on subjectivation, the cultural-historical entanglement of the Modern, technoscientific enterprise and Capitalism are also an element at the core of the type of subjectivities that mathematics education has stived to produce. Not in vain is mathematics education in recent times closely governed by agencies such as the OECD and its PISA (see e.g., Andrade-Molina, 2022).

If this is the case, what can be said about the proposal for change sketched above? What if efforts to align the aims of mathematics education with the desire to mitigate the socio-ecological crises are merely ritualistic gestures that give the illusion of a solution? Here we need to engage in a new form of critique. According to Žižek (2011), many contemporary institutional practices are characterized by the creation of a semblance of change while allowing the underlying structures of power and exploitation to remain unchallenged. This is one of the mechanisms of the ideological functioning of Capitalism, and mathematics education is deeply entangled in it (Straehler-Pohl & Pais, 2014). In this context, initiatives that appear progressive but lack substantive impact might function as ideological rituals by providing a sense of participation and moral satisfaction without addressing the deeper, structural causes of ecological degradation. Popkewitz (1982, 1988) emphasized the performative nature of many educational reforms and efforts to strive for change, arguing that they often end up reinforcing existing power structures rather than disrupting them. He highlighted how reforms or changes frequently aim to adjust practices within the existing framework of education, thus failing to challenge the deeper socio-economic and political contexts that shape educational goals and methods.

Efforts that only superficially integrate socio-ecological themes into the curriculum may thus *simulate* solutions rather than enact real change. For example, incorporating a few environmental examples in mathematics problems or holding occasional workshops on sustainability can create the appearance of addressing the crises, but without a fundamental shift in the educational paradigm and societal values, these actions might be little more than performative gestures. Following Žižek, then these ritualistic activities can serve to maintain the *status quo* by channeling potential radical energy into harmless activities. In this sense, incremental and superficial changes in mathematics education could serve to "pacify" calls for more radical transformation, thereby preventing more significant and necessary systemic changes from occurring. Žižek speaks about symbolic acts that satisfy our need to "do something" while avoiding real sacrifice or change. Educational reforms that do not challenge the underlying capitalist and technoscientific paradigms may fall into this category, allowing educators and policymakers to claim they are addressing the ecological crises without fundamentally altering the systems that contribute to the problem. These reforms thus run the risk of amounting to little more than lip service to environmentalist discourse rather than achieving systemic change, a potential type of "green-washing" of mathematics education practices and, overall, the school mathematics curriculum. Such "green-washing" would not be more than the educationalization of the risks of the multiple socio-ecological crises that mathematics education is called to solve.

The concept of the "ideology of certainty" elaborated by Borba and Skovsmose (2004) can be particularly illuminating here also with reference to the aforementioned problems connected to the (mis)use of mathematical modeling in the classroom. As understood by these authors, this is an ideology arising primarily in mathematical classrooms which fosters a belief in the absolute accuracy and objectivity of mathematical knowledge and models, which can create a false sense of security and control over complex issues like climate change (cf. also Skovsmose, 2023; Mbembe, 2021). By relying heavily on mathematical models to address climate change, educators and policymakers might unwittingly perpetuate this ideology, giving the impression that mathematical solutions and approaches are infallible and/or unquestionable. Borba and Skovsmose warned that this ideology can mask the inherent uncertainties and limitations of mathematical models, leading to an over-reliance on these tools and potentially overlooking other crucial dimensions of the ecological crises. This without even mentioning that new forms of mathematical models, such as those underlying current Artificial Intelligence technologies, create new forms of certainty that are not only problematic in themselves, but are also a new force contributing to the socio-ecological crises (e.g., see Andersson & Valero, in this volume).

Furthermore, illusions arising in the classroom connected to the mathematization of environmental problems with the purpose to sensitize towards them can ultimately go in the direction of nurturing "green capitalist" solutions with doubtful or detrimental environmental impact. Think for instance of the current carbon credit offset market and its connection with the idea that we can quantify the carbon emission of each and every human activity. While this idea is frequently used in the classroom to raise awareness about individuals' environmental impact, these activities can also be seen as actively connected to the push for adoption of carbon offsetting mechanisms as a major institutional solution to the environmental crises, ultimately masking the reality that "carbon offsets are primarily used to justify ongoing emissions, rather than reduce them" (Cullenward et. al., 2023, p. 1085).

Overall, the ideology of certainty reflects what Jablonka and Gellert (2007) described as the "myth of the infallibility of technology" (p. 8; cf. Straehler-Pohl, 2017). Applied to environmental crises, this myth implies that there is no doubt that a solution will ultimately come from advanced technological interventions, possibly including, say, forms of extreme geoengineering. Latour (2017), criticized this *hubris* as a particular type of frenzy of technoscientific domination which serves to acquiesce in many the anxiety related to the upcoming environmental disaster. The key, in this perspective, is to accelerate with even more technoscientific advancements — surely the invention of a new device for zero-emission energy is just around the corner! Of course, mathematization is fundamental for this pursuit. And for mathematization to generate a sense of certainty, mathematics education has to promote a subjectivation that inserts in individuals and populations the epistemic virtues of mathematics, all of which are Modern in character (Valero, 2023). This is why the typical proposals of change in mathematics education may not break the dominant educational-political-cultural-economic logic that governs the very same functioning of the different institutions implicated in producing the current socio-ecological crises.

ALTERNATIVE ORIENTATIONS?

Some mathematics educators might argue that the most important task of mathematics education is to provide universal access to a high-quality education that equips students with both strong mathematical knowledge and skills and the ability to transfer and apply the former to real-world

problems. From this perspective, the integration within mathematics education of the modelling of climate environmental phenomena would appear solely in the positive light of offering a means of fostering mathematical knowledge, developing transfer and application skills, and also raising environmental consciousness. To these mathematics educators the critical approach adopted in this paper could perhaps appear to be counterproductively pessimistic and ultimately leading to the overlooking of the significant real-world impact that mathematics can have — leaving aside a potentially divisive and paralyzing effect in the field itself that critical approaches are often condemned for. As Coles, Solares-Rojas and le Roux (2024) pointed out, the usual practices of mathematics education, if they remain unchallenged, run the risk of becoming, in the words of Latour (2004), like those "mechanical toys that endlessly make the same gesture when everything else has changed around them" (p. 225). Therefore, they argued that for mathematics education to produce significant new actions, "[t]here is an urgency to (re)evaluate the "reach" of these practices of mathematics education and consider both what ecological collapse means for mathematics education and whether mathematics education might have a meaningful response" (Coles et al., 2024, p. 166).

To truly go in the direction of addressing the ecological crises by means — or perhaps despite — mathematics education, a radical rethinking thus seems to be required: one that moves beyond the usual, learned responses to reform mathematics curricula and practices, which may easily turn into symbolic gestures not challenging the core principles and structures of the current educational paradigm. Drawing on the analytical moves of studies on the cultural politics of mathematics, it is possible to engage in a critique of the types of typical proposals by troubling mathematics education as part of the network of practices and power that make it a central element in the school curriculum. It is also possible to focus on the economic critique that posits mathematics education as central for the function of mathematical subjectivation in capitalist economies and their organization. These problematizations are important to disturb the belief that better mathematical curricula and practices aligned to internationally proclaimed sustainability goals can potentially make a fundamental difference. This critical task requires us to go beyond the established limits and possibilities of mathematics education.

An objection to the critical stances in mathematics education that we propose here could be that no concrete, actionable proposals of change in practice are offered here. To such objection we first respond that the ethical responsibility of research as a serious intellectual activity engaged with the world and its problems is to strange the familiar, to provide understanding, and to theorize. Research is a very political act with the potential to make new imaginations possible. Without critique, it is unrealistic to disrupt the strength of reproduction built in many well-intentioned proposals for change in mathematics education, also in times of socio-ecological crises. A second response is that critique is at the base of the possibility of articulating new imaginations not only conceptually but also in what is actionable. This is indeed a collective challenge as we move—hopefully—towards new unexplored directions.

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